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AFGWC/TN - 88/001

AIR WEATHER SERVICE

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THE AFGWC AUTOMATED REAL-TIME CLOUD ANALYSIS MODEL

BY

1LT RAYMOND B. KIESS

LT COL WILLIAM M. COX

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AF GLOBAL WEATHER CENTRAL

MARCH 1988

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)
AIR FORCE GLOBAL WEATHER CENTRAL
OFFUTT AFB NE 68113-5000

AFGWC/TN-88/001, The AFGWC Automated Real-Time Cloud Analysis Model, March 1988, has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

1a. Report Security Classification: UNCLASSIFIED.

3. Distribution/Availability of Report: Distribution authorized to U.S. Government agencies only, to protect information otherwise releasable only IAW DOD Instruction 7930.2, 1 April 1987. Other requests for this document shall be referred to HQ AFGWC/CV.

4. Performing Organization Report Number: AFGWC/TN-88/001.

6a. Name of Performing Organization: Air Force Global Weather Central.

6b. Office Symbol: AFGWC/SDDC.

6c. Address: Offutt AFB, NE 68113-5000.

11. Title: The AFGWC Real-Time Cloud Analysis Model.

13a. Type of Report: Technical Note.

14. Date of Report: March 1988.

15. Page Count: 91.

17. COSATI Codes: Field--04, Group--02.

18. Subject Terms: CLOUD ANALYSIS, meteorology, nephanalysis, polar orbiting satellite data.

19. Abstract: The RTNEPH (Real Time NEPHanalysis) model replaced the 3DNEPH (3-Dimensional NEPHanalysis) model in August, 1983 as the AFGWC (Air Force Global Weather Central) automated cloud analysis model. It uses a horizontal grid spacing of 25 nautical miles and uses four floating layers in the vertical. The RTNEPH uses visual and infrared data from meteorological satellites as well as surface observations, radiosonde data, and aircraft reported data to produce its analysis. A capability exists to manually modify the analysis to correct deficiencies. This nephanalysis is then used as input for AFGWC's cloud forecast models and is stored for climatological purposes by the USAF Environmental Technical Applications Center. The RTNEPH is scheduled to undergo a technical enhancement to incorporate multi-spectral techniques, use finer resolution satellite data, and produce a 12.5 nautical mile resolution analysis. Keywords:

20. Distribution/Availability of Abstract: Same as report.

21. Abstract Security Classification: UNCLASSIFIED.

22a. Name of Responsible Individual: Raymond B. Kiess.

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22c. Office Symbol: AFGWC/SDDC.

PREFACE

The purpose of this Technical Note (TN) for the AFGWC Real-Time Nephanalysis (RTNEPH) is to replace AFGWC TM 78-002, the AFGWC Automated Cloud Analysis Model. This new TN will provide updated information to reflect the implementation of the RTNEPH, replacing the previous 3DNEPH model, in August 1983.

The earlier Technical Memorandum, AFGWC TM 78-002, The AFGWC Automated Cloud Analysis Model, by then Major Falko Fye provided an excellent reference on cloud analysis techniques at AFGWC. This updated TN preserves as much as possible, the structure and content of that reference.

The authors are indebted to several people who contributed to the completion of this project:

- Major Tim Crum, AFGWC/SDD, for his many reviews, advice, and energy for this project.

- 1st Lt Tom Hamill, AFGWC/SDDC, for his assistance in preparing the figures and reviewing the text.

- The many people who reviewed this TN:

  Mr Arthur Gulliver, AFGWC/DO
  Col Falko Fye, AFGWC/SD
  Mr Charles Cook, AFGWC/SD
  Lt Col Michael Kelly, AFGWC/DOX
  Lt Col Robert Borchers, AFGWC/SDD
  Capt Kirk Poore, USAFETAC
  Mr. Sam Hall, AFGWC/SDDC

- The typists in the AFGWC Word Processing Center.

1ST LT RAYMOND B. KIESS
LT COL WILLIAM M. COX
March 1988

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SECTION 1. INTRODUCTION

The RTNEPH (Real Time NEPHanalysis) model replaced the 3DNEPH (3-Dimensional NEPHanalysis) as the Air Force Global Weather Central's (AFGWC) cloud analysis model in August, 1983. Just as its predecessor 3DNEPH (Fye, 1978) did, the RTNEPH continues to blend high resolution satellite data and conventional data to perform an automated cloud analysis at 25 nm horizontal resolution.

RTNEPH is similar to the 3DNEPH in terms of basic functions and algorithms. However, RTNEPH is written in ANSII standard FORTRAN 77 vice FORTRAN V and enjoys much better overall program documentation than 3DNEPH. Coupled with structured software design techniques, RTNEPH is easier to maintain and to improve with new algorithms.

The RTNEPH contains two major differences from 3DNEPH - the database definition of the vertical structure and the addition of diagnostic information. RTNEPH employs four floating vertical layers vice the 15 fixed layers in 3DNEPH. This allows a greater vertical resolution as cloud bases and tops are sharply defined, removing constraints on applications sensitive to cloud layer definition. The addition of diagnostic information allows better quality control techniques and more detail for users of the database.

The primary use of RTNEPH is to initialize AFGWC cloud forecast models. AFGWC also sends the data to USAFETAC/OL-A where they are stored for climatological purposes. This also makes RTNEPH useful for cloud climatology studies; recent examples are Hughes and Henderson-Sellers (1985), Curry and Herman (1985), and Henderson-Sellers (1986). Combined with the 3DNEPH, RTNEPH provides a long-term cloud climatology database, especially useful with the recent interest in cloud climatology in the world community (Shiffer and Rossow, 1983).

We'll discuss the features of RTNEPH important for users to know. These include the grid system; database contents; the satellite, conventional, merge, and bogus processors; quality control; and applications. In addition, we'll discuss RTNEPH's planned future.

SECTION 2. GRID SYSTEM

2.1 Resolution Considerations

The RTNEPH grid is a 25 nm (eighth mesh) polar stereographic grid with up to four cloud layers at each grid point. This grid was determined by a number of considerations described below.

2.1.1 Input Data

The input data for RTNEPH have characteristics dictating a compromise between fine and coarse resolution. The satellite data used by RTNEPH are taken from the AFGWC Satellite Global Data Base (SGDB). The SGDB uses unprocessed meteorological satellite data, typically at 1.5 nm resolution, and processes them to give smoothed grayshade values on an approximately 3 nm resolution grid. To get a representative sample of cloud layers, a set of points (RTNEPH currently uses an 8 x 8 array of SGDB values) must be combined. If too few points are combined, the analysis loses the ability to determine cloud layer structure. If too many points are combined, however, the analysis loses the fine detail provided by the satellite data. Conventional observations (surface reports, RAOBS, PIREPs, etc.) are also used as input to RTNEPH. These observations typically describe an area with a radius of 20 to 50 nm. If the resolution of the grid is too coarse, many conventional observations may occur within a grid box causing some to be discarded or merged. However, too fine a grid would let the conventional data distort the analysis provided by the satellite data.

2.1.2 Hardware Restrictions

The RTNEPH model is run many times per day and must produce timely analyses. In general, as grid spacing decreases, computer storage and processing time increase. In order to meet production timelines, the RTNEPH couldn't have a grid size of less than 25 nm on the then present AFGWC computer system.

2.1.3 The 3DNEPH Model

The predecessor to the RTNEPH model, the 3DNEPH, faced many of the same requirements as RTNEPH. Its designers chose the eighth-mesh (25 nm) resolution to satisfy their requirements (Fye, 1978). Staying with the same horizontal resolution and grid projection made the conversion to RTNEPH much simpler.

2.2 Horizontal Grid

The RTNEPH grid is overlayed on a polar stereographic projection true at 60° latitude. There are two grids, one for each hemisphere. Each grid is a subset of the AFGWC Whole-mesh Reference Grid, but has a resolution of approximately 25 nm rather than 200 nm, and is therefore called an eighth-mesh grid. Each grid is a 512 x 512 matrix of points, with the poles located at grid point (257,257). Each grid has a total of 262,144 points (Hoke et. al., 1981).

Only a small number of points in the eighth-mesh grid need be processed at any one time. Therefore, the grid is subdivided into a set of 64 RTNEPH boxes, arranged in an 8 x 8 matrix, and numbered 1 to 64 (Figures 2.1 and 2.2). Each box contains a 64 x 64 set of eighth-mesh points. If a point is off the map projection (beyond the equator), it is not processed. The four corner boxes, 1, 8, 57, and 64, are all completely off the map projection and are not included in the RTNEPH database.

2.3 Vertical Grid

The data in RTNEPH are arranged vertically in up to four cloud layers at each point. Each layer has information on cloud amount, type, base and height. The layers are sorted by cloud base, with the highest base in layer 1. The layers can overlap, and the top and bottom boundaries are not fixed. This is the primary database difference between the 3DNEPH and RTNEPH. 3DNEPH used a fixed 15 layer vertical stack. However, there were rarely more than four layers at any one point, so RTNEPH was designed to restrict the number of layers, but let them float vertically instead, providing finer vertical resolution.

The layer heights can range from the surface to 21900 m mean sea level (MSL). The spacing resolution is 30 m below 6000 m, and 300 m above 6000 m.

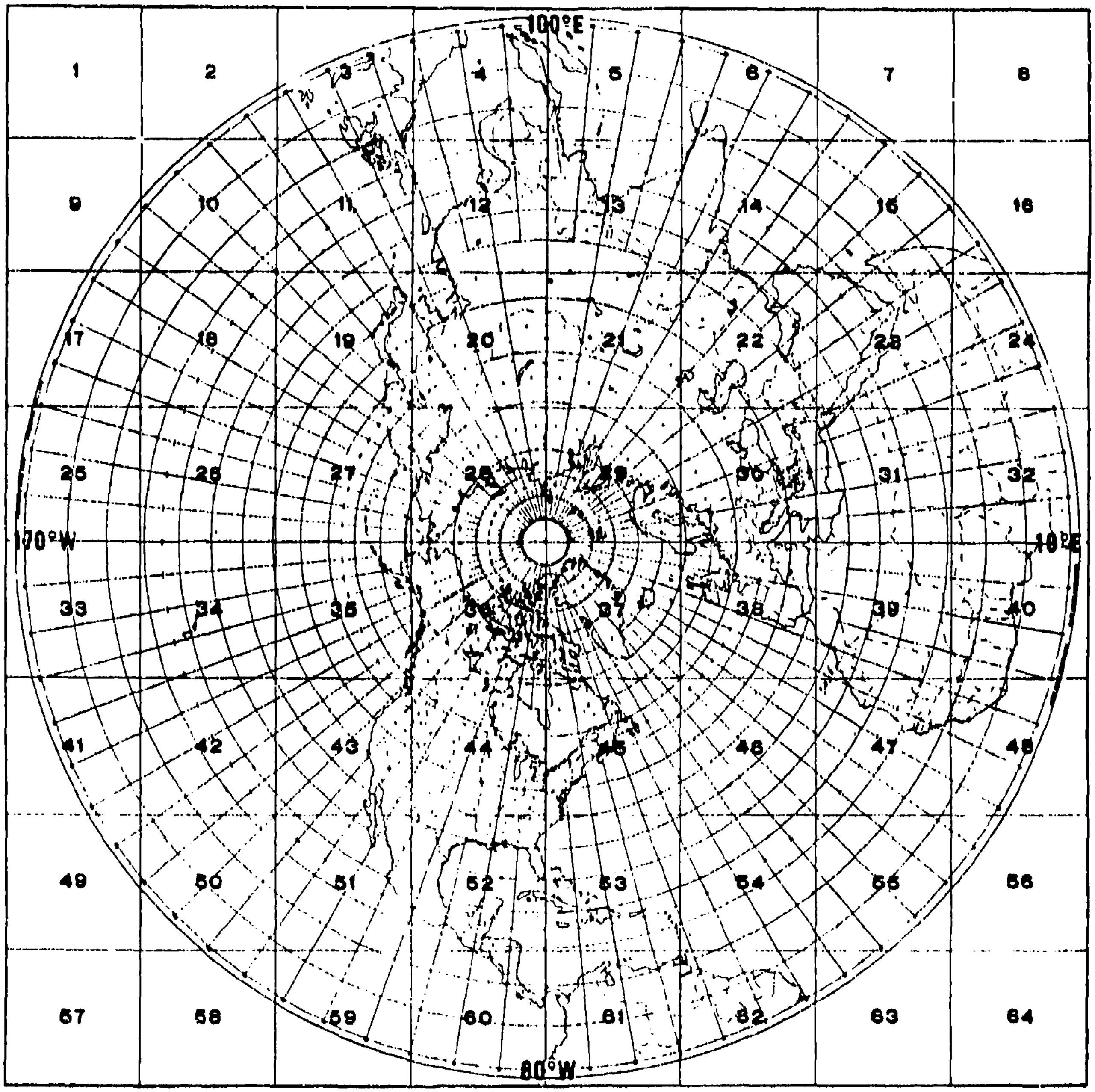


Figure 2.1 Northern Hemisphere RTNEPH grid over a polar-stereographic projection. Each square partition is an RTNEPH box (1600 nm on a side). Corner boxes are not used.

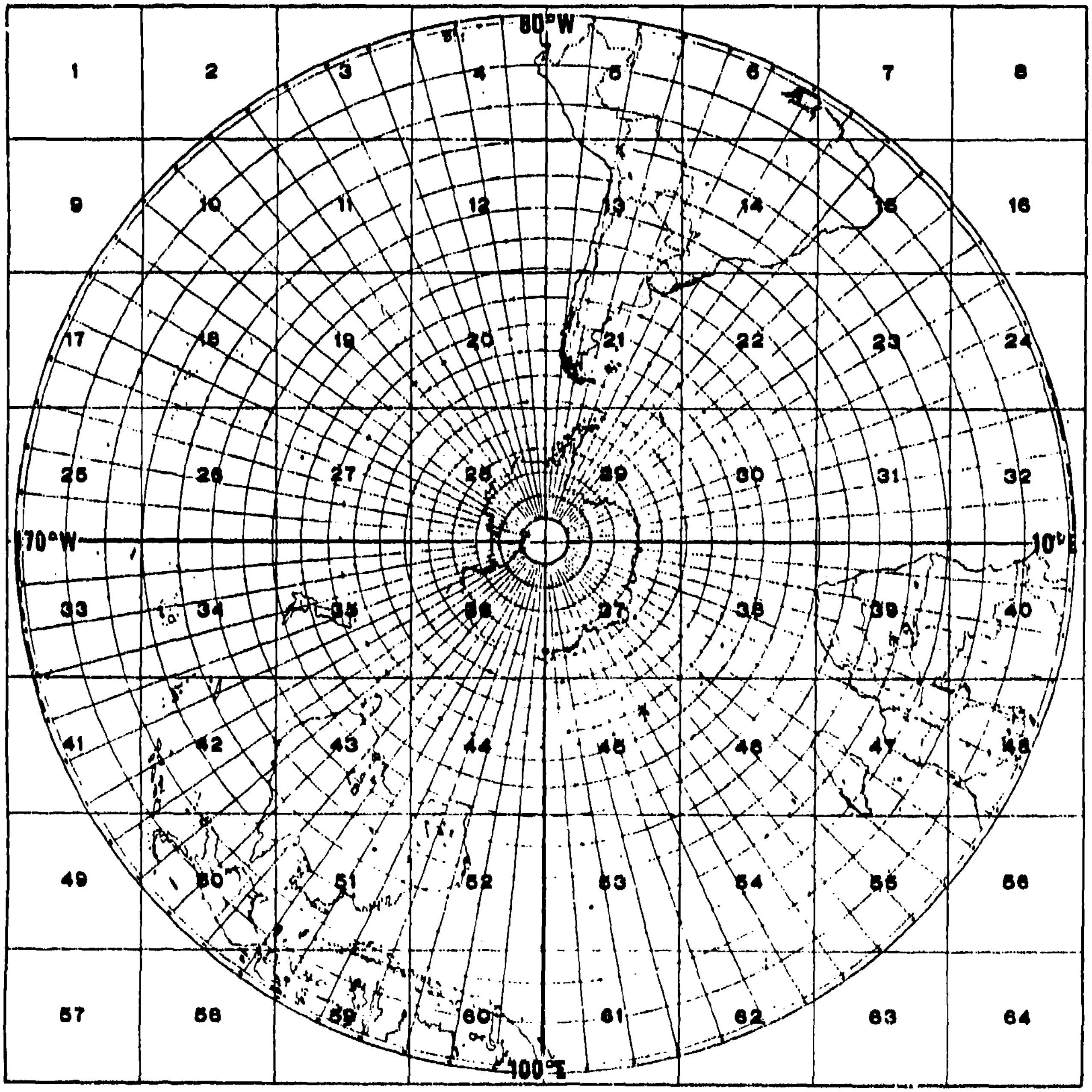


Figure 2 2 Southern Hemisphere RTNEPH grid.

SECTION 3. SYSTEM OVERVIEW

In this section, we'll briefly discuss the different RTNEPH modules, the RTNEPH and supporting databases, and the RTNEPH operating environment.

3.1 Basic RTNEPH Functions as Processing Modules

One of the basic philosophies of the RTNEPH design was to construct processing modules along the lines of the major functions. This modular approach permitted a software structure easier for programmers and systems analysts to learn, maintain, and improve. Additionally, the modular approach permitted processing to be distributed over different mainframe computers, thus permitting an expedient processing of as much data as possible.

There are six basic modules within the RTNEPH system. The three primary modules and their functions are:

a. Satellite Processor, which performs a cloud analysis based on satellite data only and produces an intermediate database.

b. Conventional Processor, which builds an intermediate analysis based solely on conventional data (surface observations, rawinsonde observations, and aircraft pilot reports).

c. Merge Processor, which merges the satellite and conventional analyses into the actual RTNEPH database.

These three modules make up the core of the RTNEPH system as shown in Figure 3.1. The system is completed by adding three support modules, namely:

a. Bogus Processor, which allows manual modification to correct deficiencies in the automated analysis.

b. Display Processor, which allows specific parameters to be displayed in formats useable to meteorologists.

c. Driver Module, which schedules the execution of the Satellite and Merge Processors based on availability of data and computer resources.

These six processor modules come together as a system as shown in Figure 3.2.

3.2 Support and Peripheral Databases

Figures 3.1 and 3.2 provide a road map for the software modules themselves. However, equally important are the databases which provide direct data inputs or provide data supporting the analysis of conventional or satellite data. Examples of these databases are:

a. Geography/Terrain database, which includes terrain heights as well as indicators of geography type (e.g., land, water, coast, ice-covered water) for the 1/8th mesh grid.

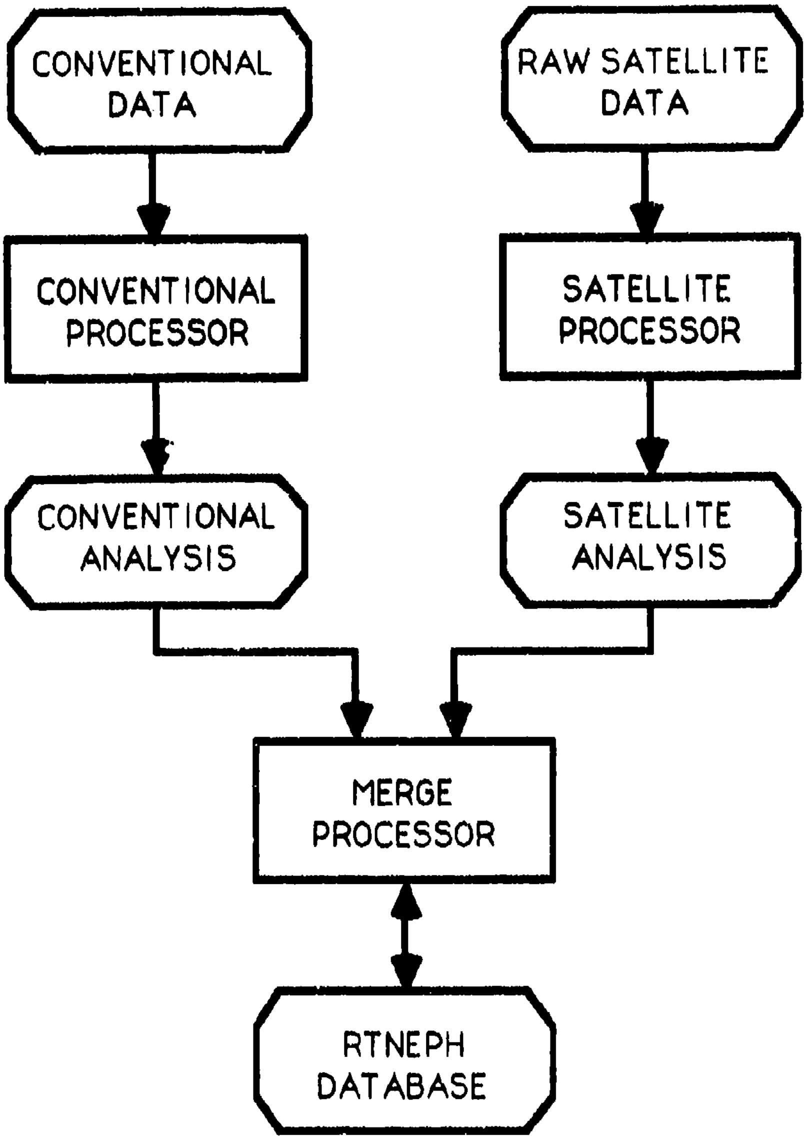


Figure 3.1 Relationship of the primary RTNEPH processors and analyses.

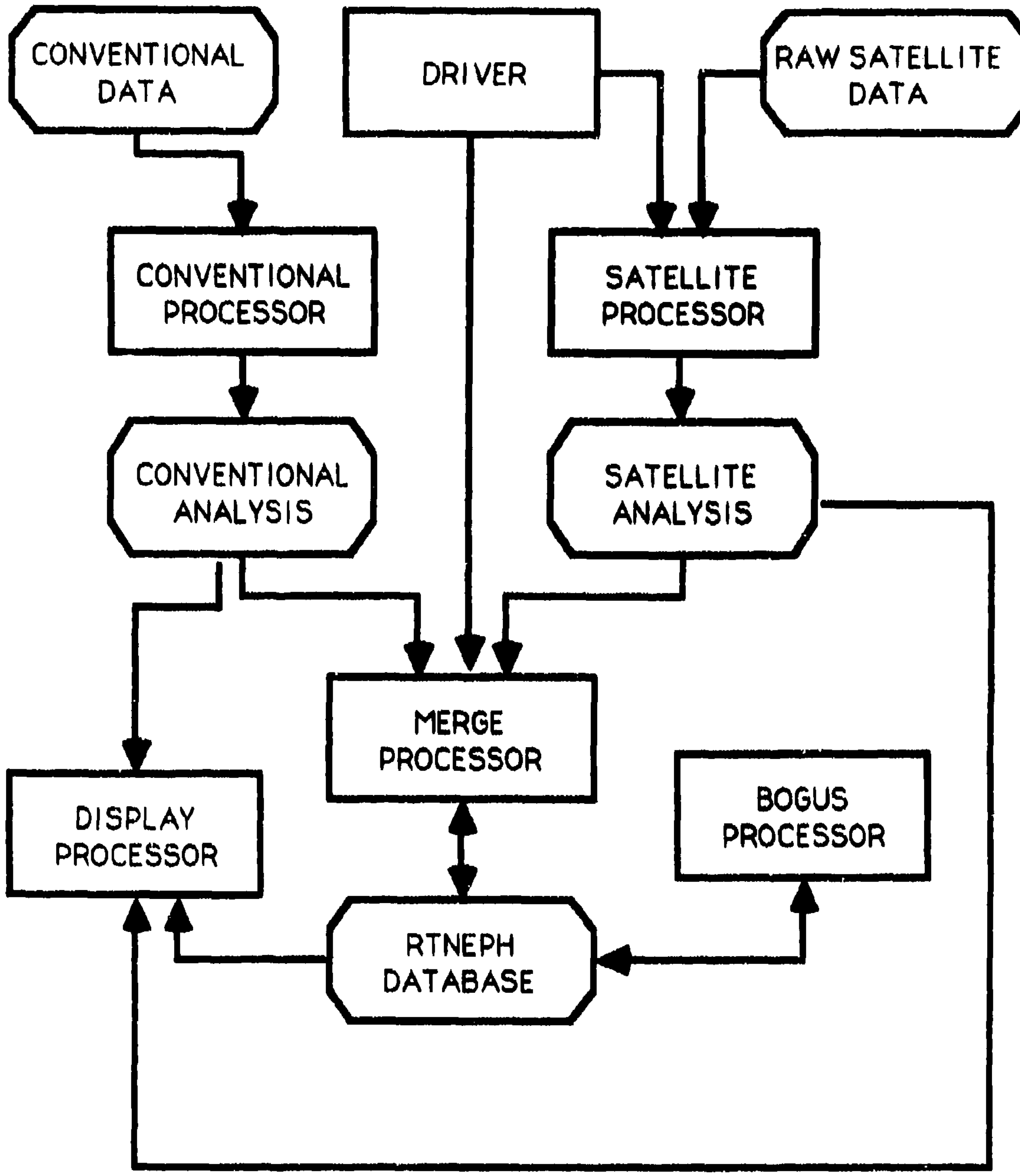


Figure 3.2 Relationship between RTNEPH processors and databases.

b. Satellite Global Data Base (SGDB), the array of satellite data represented by grayshades for 3 nm resolution pixels.

c. Background brightness database, which contains a background brightness for the visual satellite data at 25 nm resolution to be compared against for determining cloud-covered pixels.

d. Surface temperature database, which contains surface temperatures at 1/8th mesh for the infrared satellite data to use for determining cloud-covered pixels.

e. Upper air temperature database, used to calculate the tops of cloud layers derived from infrared satellite data. The resolution is 200 nm or whole mesh.

f. Conventional reports database, containing the conventional reports used in the conventional processor.

g. Tuning databases, sets of processing parameters used in the individual processors and easily modified by meteorological database analysts to adjust or improve the analysis.

Just as we need to understand the linkage between processors, we need to understand the linkage between the processors and these databases as shown in Figure 3.3.

3.3 General Contents of the RTNEPH Database

A detailed description of the contents and meaning of the database entries is provided in Section 8. However, consistent with providing a general description of the processing structure, we'll provide a general description of the database. The database information at each grid point can be divided into four groups:

a. The total cloud amount, present weather, visibility, and valid time of the data at the grid point.

b. Data for each of the (up to four) layers, specifically layer cloud amount, layer cloud type, layer base and layer top.

c. Layer source information which defines, for each of the layers, whether the layer was derived from satellite data or conventional data, whether the base or top was estimated, etc.

d. Diagnostic information, primarily for quality control and studies requiring detailed data source description, which includes indices for denoting whether infrared data were used, whether visual data were used, and so on. These diagnostic factors will be fully discussed in the database section.

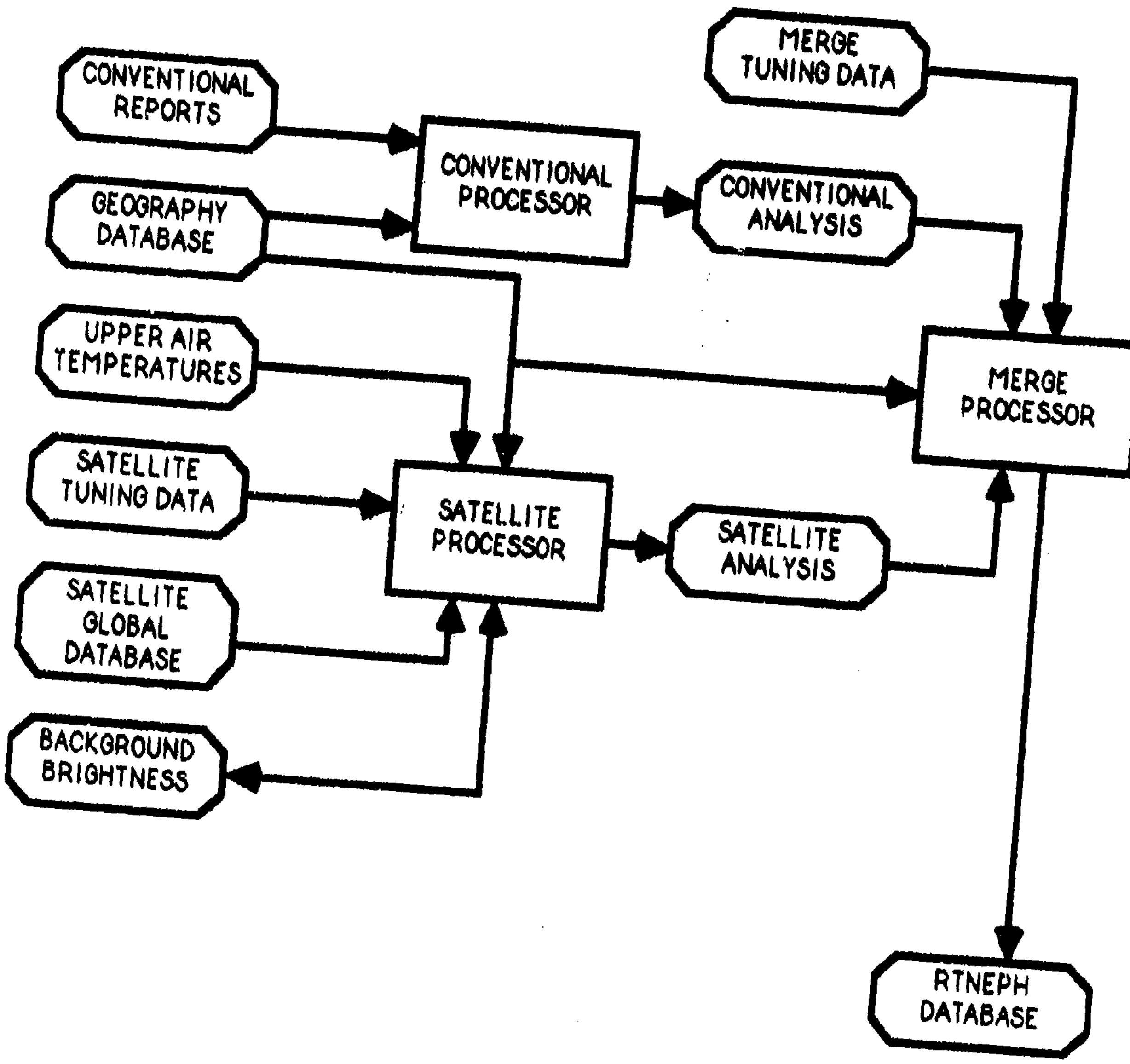


Figure 3.3 Relationship between the primary processors and their supporting databases

3.4 Operating Modes

RTNEPH operates in one of three modes in the AFGWC production cycle: sprint, non-sprint, and update (synoptic). Each operation mode is for a specific purpose.

3.4.1 The Sprint Cycle

The sprint cycle, as suggested by its name, is designed to incorporate a quarter orbit of satellite data as quickly as possible into the RTNEPH and from there, into a cloud forecast model. The sprint cycle is triggered by the receipt of a quarter orbit of data into the AFGWC computer systems. The data are mapped into the SGDB and then the RTNEPH Satellite and Merge Processors process the RTNEPH boxes containing new satellite data. The RTNEPH output is manually quality controlled and if need be, changes are input via the Bogus Processor. The sprint cycle is outlined in Figure 3.4.

3.4.2 The Non-Sprint Cycle

The non-sprint cycle is similar to the sprint cycle except the timeliness, manual quality control, and immediate cloud forecast model input restrictions are lifted. It too, operates on a quarter orbit by quarter orbit basis. Though the non-sprint isn't as time critical as a sprint, it is extremely important for the complete database. The non-sprint cycle is outlined in Figure 3.5.

3.4.3 The Update (Synoptic) Cycle

The purpose of the update cycle is to incorporate as much data as possible every three hours before making a "synoptic" copy. Unlike the sprint and non-sprint cycles, the update cycle operates on a hemispheric basis. All remaining unprocessed quarter orbits from the last update cycle are processed in the Satellite Processor. Then this data is merged with the most recent conventional data. Finally, a snapshot of the database is created to make the synoptic copy. The northern update is built approximately two hours after data time (00Z built at 02Z) and the southern is built three hours after data time. The update cycle is outlined in Figure 3.6.

3.4.4 Conventional Data Processing

RTNEPH processes conventional data upon receipt of regular surface data. These updates are normally once an hour. Therefore, the RTNEPH Conventional Processor runs about once an hour and the data it produces is available for the Merge Processor.

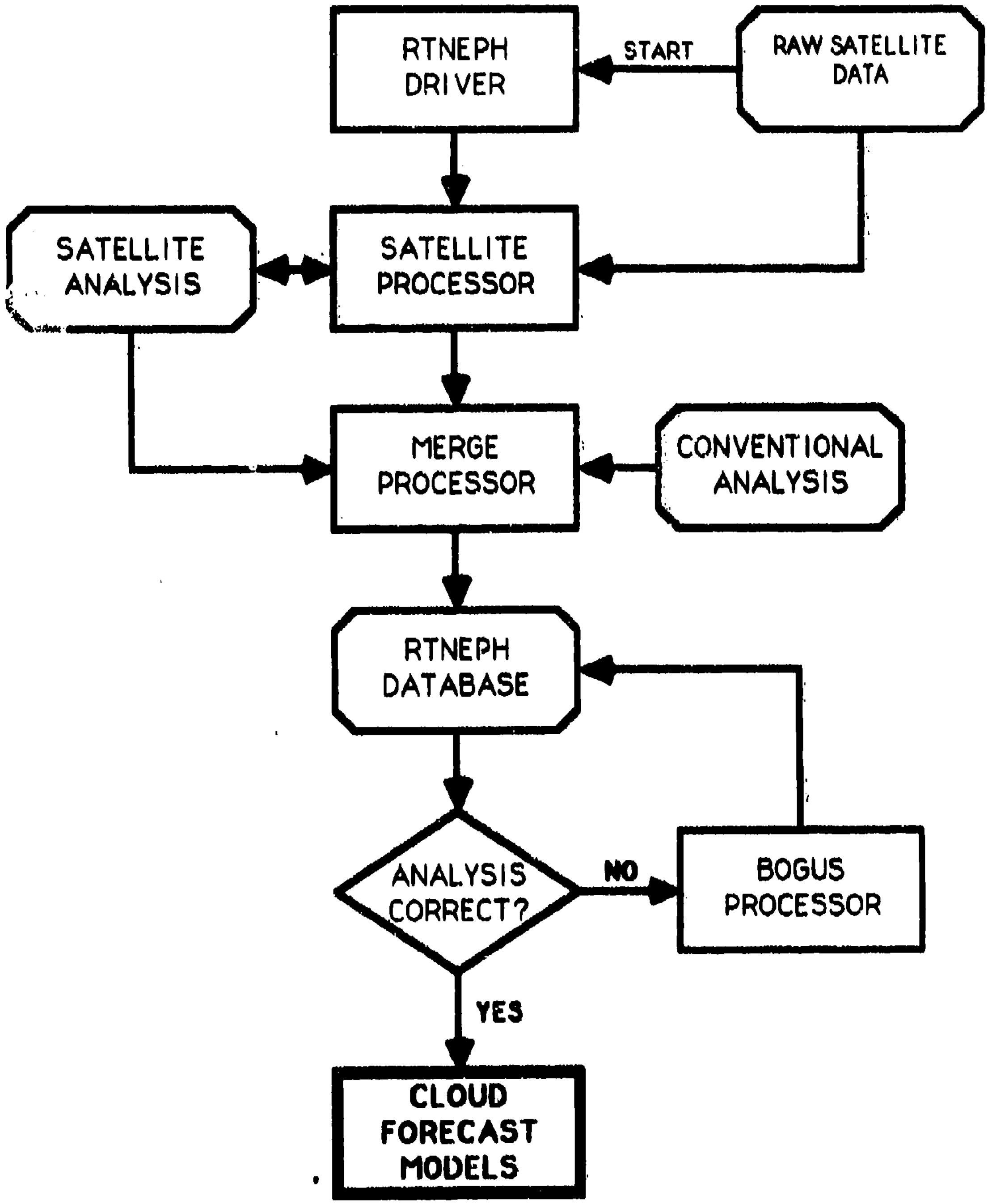


Figure 3.4 Processing flow of the AFGWC Sprint Cycle. The Sprint Cycle operates on a quarter orbit basis.

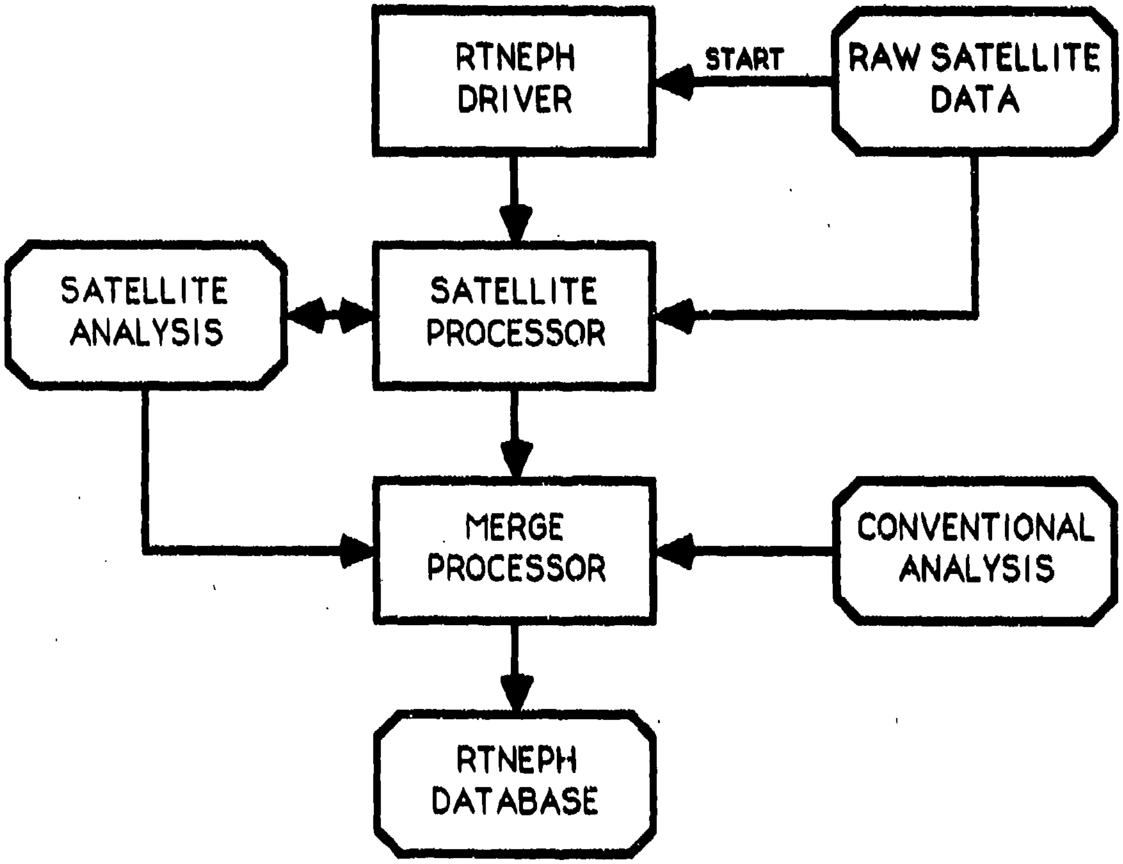


Figure 3.5 Processing flow of the AFGWC Non-Sprint Cycle. The Non-Sprint Cycle operates on a quarter-orbit basis.

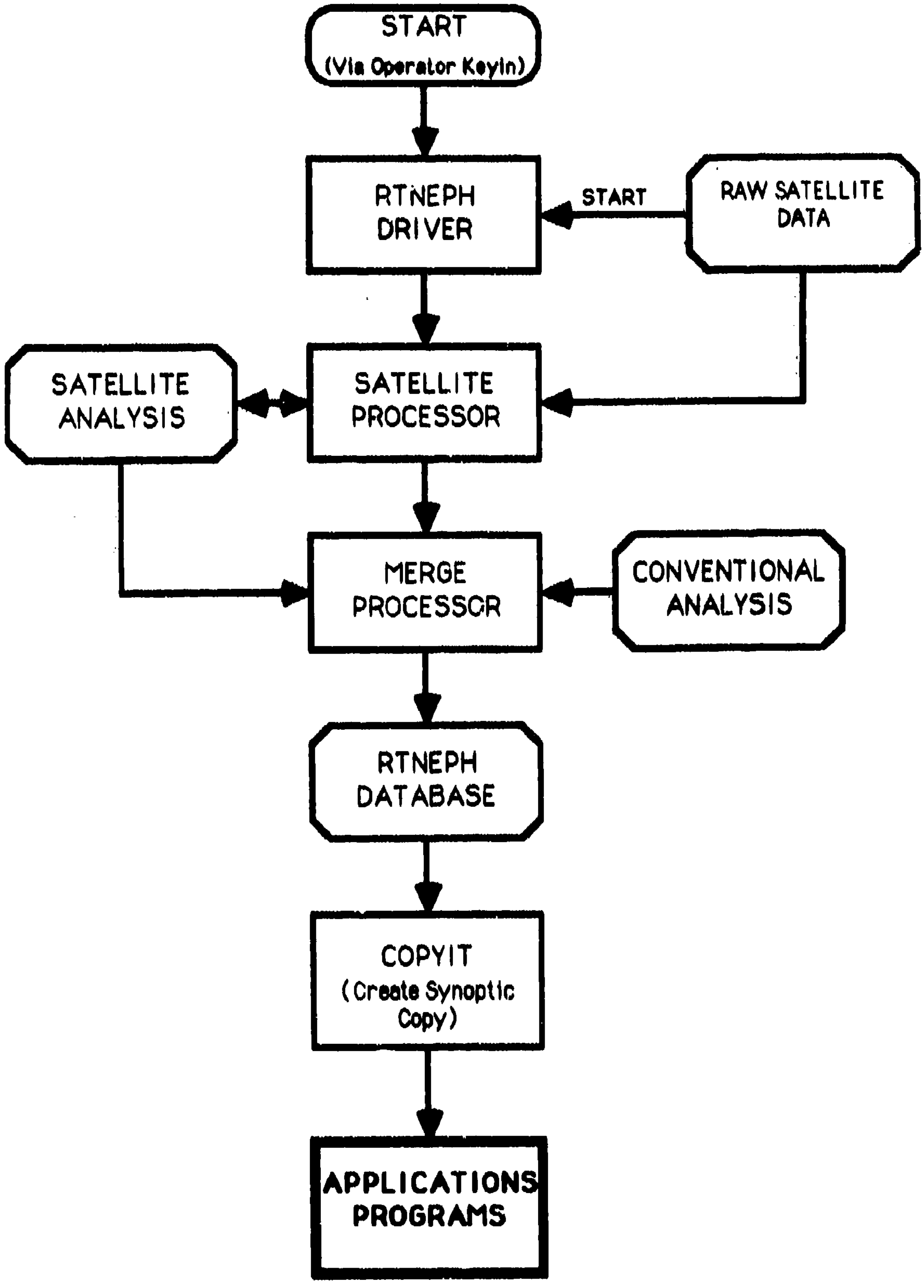


Figure 3.6 Processing flow of the AFGWC update cycle. The Update Cycle operates on a hemispheric basis.

SECTION 4. CONVENTIONAL PROCESSOR

The RTNEPH Conventional Processor remains nearly the same as the 3DNEPH Conventional Processor with the following exceptions:

a. It conforms to the RTNEPH vertical layer format (4 floating layers) rather than the 3DNEPH format (15 fixed layers) and

b. It is written in FORTRAN 77 instead of FORTRAN V.

Since the overall algorithm and flow remains nearly the same, much of this section is taken from the 3DNEPH Technical Memorandum (Fye, 1978).

The Conventional Processor takes surface, aircraft, and upper air reports from the AFGWC database; sorts, screens, and combines reports to produce a gridded eighth-mesh database of cloud and weather information. This database, known as the Best Reports File, contains only gridpoints for which data are available and is in RTNEPH format - including the vertical levels. Figure 4.1 shows the overall flow of the process. Table 4.1 provides an idea of the quantity of data processed. The Conventional Processor is broken down into four parts: the surface data processor, the upper air data processor, the aircraft processor, and the decision tree processor. We'll discuss each processor in detail.

4.1 Surface Data Processor

The surface data processor determines cloud amounts for up to four layers from several sources of validated surface reports.

4.1.1 Data Types and Time Considerations

Cloud data are extracted from synoptic, METAR, and Airways coded reports. If more than one type of report is available at a given time, all unique information from both reports is used to produce a composite report. Conflicting information is resolved with consideration for data timeliness and implicit data quality. All surface-based observations of cloud data are ranked above upper air sounding data. All hourly and special surface reports valid since three hours before the analysis valid time are considered. Figure 4.2 shows the typical rate of data flow into AFGWC.

4.1.2 Present Weather

Present weather is converted to a weather factor (KWEA) and is used to determine cloud layers and types. Table 4.2 shows the conversion to KWEA. The most significant present weather element, from WMO Code 4677, is included as an independent parameter in the RTNEPH database. If fog or haze is superseded by a reported higher value, a flag is set to indicate this. This information is used later by the Merge Processor. Missing weather is reported as 127.

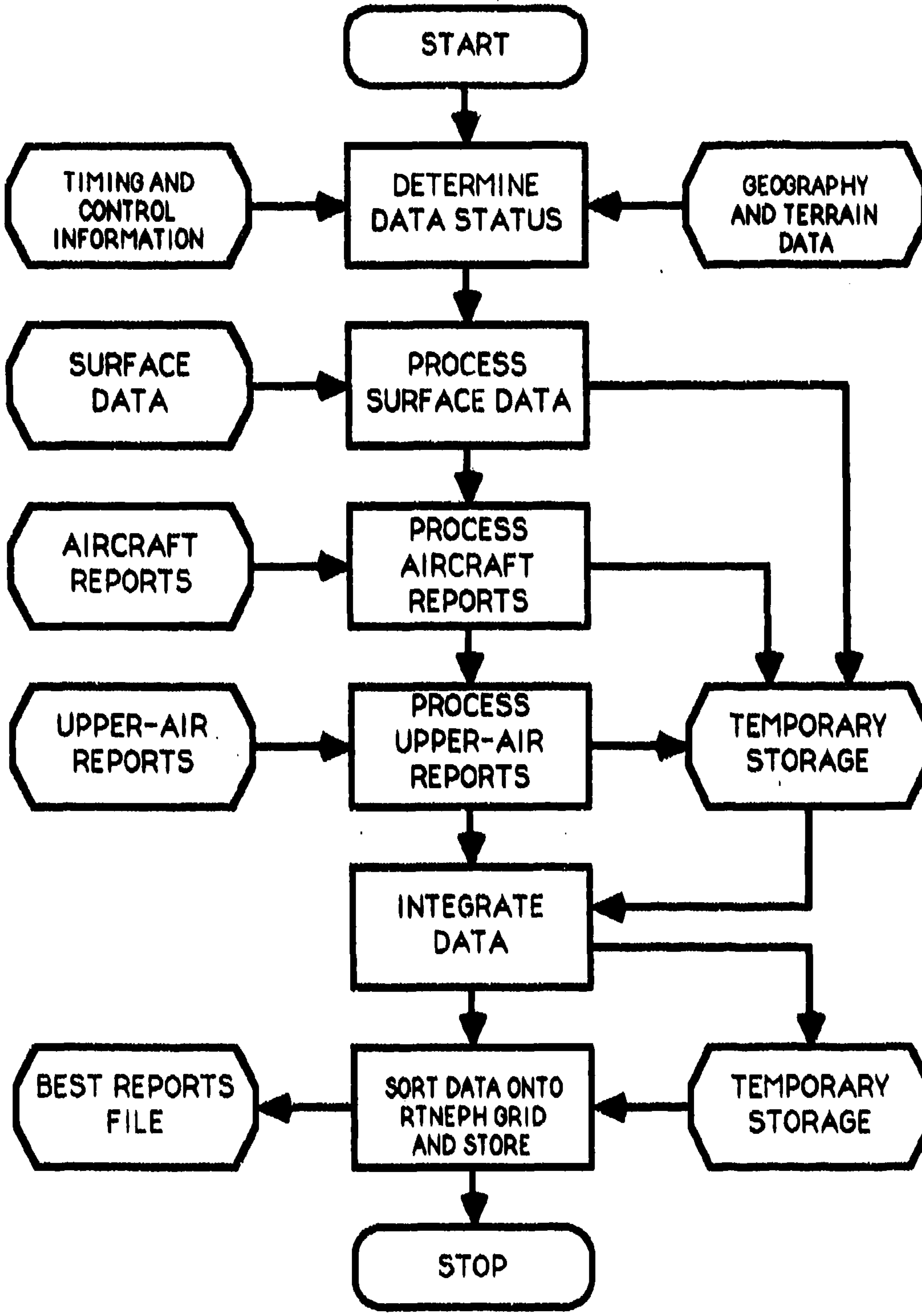


Figure 4.1 Functional flow chart of the Conventional Processor (from Fye, 1978).

	N.H. VALID TIMES								S.H. VALID TIMES			
BOX	0Z	3Z	6Z	9Z	12Z	15Z	18Z	21Z	03Z	09Z	15Z	21Z
2	0	0	0	0	0	0	0	0	0	0	0	0
3	10	12	17	18	15	14	3	2	0	0	0	1
4	37	50	49	48	45	45	21	22	7	1	9	7
5	14	19	19	22	18	23	5	2	35	11	33	41
6	6	13	13	14	12	21	10	11	11	2	8	14
7	0	0	0	0	0	0	0	0	2	0	2	2
9	1	1	0	1	1	1	0	0	0	0	0	0
10	18	21	14	16	11	11	4	6	1	1	0	1
11	44	51	50	54	42	38	12	14	2	2	1	2
12	337	340	315	336	308	237	198	284	2	0	2	2
13	70	101	124	100	82	118	59	58	76	41	98	100
14	28	36	21	27	40	83	28	29	56	20	76	79
15	0	0	3	6	4	5	5	6	19	10	26	24
16	0	0	0	0	0	0	0	0	0	0	0	0
17	7	7	6	6	4	3	3	3	0	0	0	0
18	10	12	11	9	7	7	3	3	9	6	5	8
19	234	251	250	242	163	157	120	124	1	0	0	0
20	515	547	537	563	570	518	498	532	0	0	0	0
21	384	282	364	364	448	446	418	396	58	38	66	68
22	145	146	157	174	181	191	156	147	5	1	9	7
23	6	6	22	28	18	20	8	5	0	0	1	1
24	5	6	5	14	15	19	9	9	0	3	2	2
25	0	0	0	0	0	0	0	1	4	4	1	4
26	8	13	9	8	5	4	3	5	10	8	4	10
27	76	90	83	86	48	59	32	71	0	0	0	0
28	175	133	146	185	204	210	205	201	0	0	0	0
29	344	287	352	371	402	401	394	396	7	0	8	11
30	770	798	896	837	794	869	868	841	0	1	1	2
31	24	18	19	38	31	32	31	29	1	4	3	3
32	0	4	25	42	39	44	39	34	3	5	3	2
33	1	2	1	2	0	0	0	0	12	7	6	13
34	26	26	14	16	13	14	21	27	13	20	17	24
35	55	79	50	52	35	40	41	63	18	32	24	30
36	133	128	105	101	100	113	131	136	2	0	1	1
37	71	67	70	83	94	102	99	99	3	3	3	3
38	423	395	514	564	566	624	572	598	0	4	2	2
39	35	38	50	56	51	52	49	50	24	124	92	107
40	18	39	40	46	47	62	55	54	8	20	16	12
41	0	0	0	0	0	0	0	1	2	1	0	2
42	3	2	0	0	2	2	4	8	17	23	17	26
43	166	167	141	115	109	158	164	177	50	51	46	39
44	448	435	387	353	426	459	459	455	3	10	7	4
45	242	236	192	187	250	267	233	258	2	2	0	0
46	15	16	8	12	21	38	21	30	4	8	4	4
47	13	19	21	35	39	46	43	49	19	60	42	16
48	0	0	4	15	11	16	16	15	21	25	19	17
49	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	1	0	1	12	8	6	7
51	20	22	16	11	13	21	25	32	24	26	14	14
52	213	217	168	155	203	228	221	221	14	18	11	12
53	75	84	50	47	92	120	87	102	2	3	4	0
54	7	11	3	3	7	13	8	13	3	3	0	0
55	0	0	0	0	0	3	0	2	1	3	5	4
56	0	0	0	0	0	0	0	1	0	0	0	0
58	0	0	0	0	0	0	0	0	3	1	1	1
59	0	1	0	0	0	0	0	0	8	11	7	5
60	24	28	7	6	14	30	25	28	34	33	28	18
61	64	39	11	21	52	71	66	66	1	2	1	0
62	11	8	7	5	11	12	20	15	2	2	1	1
63	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL BEST REPORTS	5331	5303	5366	5514	5663	6068	5490	5700	625	658	732	753
UNCOMBINED REPORTS	12802	12395	12004	12575	13781	14990	13951	13687	1144	1032	1501	1410

Table 4.1 Typical numbers of conventional reports received by the RTNEPH, by RTNEPH box, time, and hemisphere. These reports are integrated to produce the "Best Reports" (from Fye, 1978).

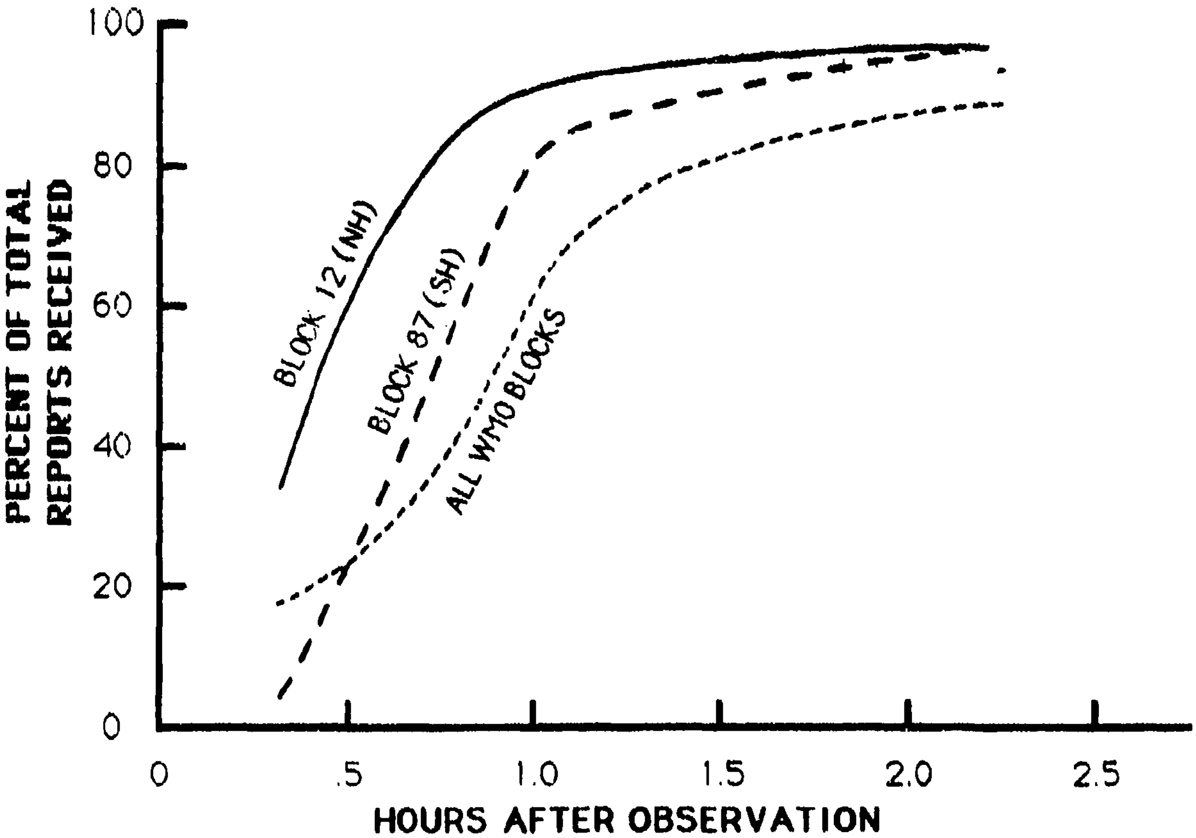


Figure 4.2 Graphic representation of conventional data flow into AFGWC. Selected areas are shown as typical examples. World Meteorological Organization (WMO) Blocks represent particular areas of the world. (from Fye, 1978).

Table 4.2

CONVERSION OF PRESENT WEATHER TO WEATHER FACTOR (from Fye, 1978)

Type of Weather	WW (WMO Code 4677)	KWEA
--	0-9	0
Mist	10	1
--	11-14	0
Precipitation in sight	15	1
Precipitation in sight	16	2
Thunder	17	2
Squalls	18	2
Funnel clouds	19	3
Drizzle, past hour	20	1
Rain/Snow, past hour	21-22	1
Rain/Snow, past hour	23	2
Freezing drizzle/rain, past hour	24	1
Rain/Snow showers, past hour	25-26	2
Showers (hail/rain/snow), past hour	27	2
Ice fog, past hour	28	0
Thunderstorm, past hour	29	2
--	30-49	0
Drizzle	50-59	1
Rain	60-69	2
Snow	70-79	2
Showers	80-89	2
Thundershowers	90-99	3
Missing weather	127 (RTNEPH code)	

4.1.3 Visibility

The horizontal visibility at the surface is converted to code values corresponding to WMO Code 4377 (Table 4.3). When the visibility is missing or not reported, the value in the database is set to 255.

Table 4.3

VISIBILITY CONVERSIONS

Input Visibility (Km)	Code Value	(Range)
0.1	00	(00)
0.1-5.0	vis X 10.1	(01-50)
6.0-30.0	vis + 50	(56-80)
30.0-70.0	(vis/5) + 74	(80-88)
70.0 +	89	(89)

4.1.4 Layered Cloud Data

When cloud amounts are specified in reports, the data are stored directly. Scattered, broken, and overcast cloud amounts are assigned 25, 75, and 100 percent coverage, respectively. Reported cloud bases are converted to meters MSL and coded according to Table 4.4.

Table 4.4

CLOUD HEIGHTS

Code Values	Definitions
0-200	30 meter increments for 0-6000 meters MSL. MSL HGT = Code x 30
201-253	300 meter increments for 6001-21900 meters MSL. MSL HGT = (Code - 200) X 300 + 6000.
254	Greater than 21900 meters MSL.
255	Height not available.

Reported cloud types are converted to code values as shown in Table 4.5. If all four RTNEPH layers contain clouds and a surface-based layer of fog is located beneath the lowest layer, the RTNEPH will indicate fog by adding 10 to the cloud type of the lowest layer (i.e., if stratus was the lowest layer, then its code value would be 12 instead of 2).

Table 4.5

CLOUD TYPES

Code Value	Cloud Type
0	Clear
1	Cumulonimbus (CB)
2	Stratus (ST)
3	Stratocumulus (SC)
4	Cumulus (CU)
5	Altostratus (AS)
6	Nimbostratus (NS)
7	Altocumulus (AC)
8	Cirrostratus (CS)
9	Cirrocumulus (CC)
10	Cirrus (CI)
25	Unknown

4.1.5 Special Considerations for Synoptic Data

Synoptic data contain limited cloud information about layered amounts. The only layered data are the amount of all low or middle clouds and the base of the lowest clouds visible. If more than one low or middle cloud layer is observed, the synoptic reports do not contain sufficient information to define each layer. The following procedures are used with synoptic reports:

4.1.5.1 Layered Amounts

Cloud height categories are determined from synoptic data. These categories are low (surface to 6500 ft above the ground), middle (6500 to 22000 ft MSL), and high (above 22000 ft MSL). Cloud amount probabilities are assigned to height categories based on the lowest cloud reported and the types of clouds.

a. If a cloud type is not observed, zero percent probability is assigned to the corresponding height category.

b. When a valid cloud type is given, 100 percent probability is assigned.

c. For a missing cloud type, 50 percent probability is assigned.

Actual layered cloud amounts are then computed, based on the total sky cover, if available, using the assumption that clouds are randomly distributed. If sky cover and cloud amounts are missing, the synoptic report is discarded.

4.1.5.2 Cloud Bases

If the base of the cloud layer is reported, then the surface data processor will use it. Otherwise, the base of clouds in the three height categories may be calculated as follows:

a. Base of low clouds (H_L) in meters AGL:

$$H_L = 670.7 - (91.46 \times KWEA) \quad (1)$$

b. Base of middle clouds is set at 3565.986 meters AGL.

c. Base of high clouds (H_H) in meters AGL:

$$H_H = 10670.732 - 44.03794 \text{ (Latitude)} \quad (2)$$

After the conversion to meters, the terrain elevation is added for MSL heights and bases are coded according to Table 4.4.

4.1.6 Surface Obscurations

Clouds are assigned with the cloud base at terrain level if a report indicates fog and/or visibility less than 1 mile (1600 meters). The cloud amount is determined from the type of fog and layer depth is determined from the horizontal visibility. Higher clouds are allowed if no obscuration (-X or X)

is reported. For a total obscuration, 100 percent cloud coverage is assumed with the base equal to the vertical visibility. If the vertical visibility is missing, the cloud base is computed as a function of the present weather.

4.1.7 Thin Clouds

Thin clouds may be reported in the Airways surface report code. Such information is stored in the Best Reports File and is useful in computing cloud thickness.

4.1.8 Total Sky Cover

When specified in a report, the total sky cover is stored and retained through all subsequent processing. When unavailable, the maximum cloud layer amount is used to arrive at a total cloud amount.

4.1.9 Cloud Tops

The surface data processor makes no assessment of cloud tops. The code value for height not available (255) is stored in the Best Reports File.

4.2 Upper Air Data Processor

An AFGWC database provides upper air data containing reports from rawinsondes, dropsondes, rocketsondes, and satellite soundings. The rawinsonde reports are screened and used to locate layered clouds by performing a moisture analysis of the available data. The stepwise procedure for cloud amount determination is described in the following paragraphs.

4.2.1 Vertical Structure

The analysis of the rawinsonde is based on the approach used in the 3DNEPH model. A vertical grid consisting of 15 layers of varying thickness from the surface to 55,000 feet is used to determine the cloud layer information. The 15 "RTNEPH" layers are divided into 6 terrain-following layers that are specified with respect to local terrain height and 9 layers that are specified with respect to mean sea level (MSL). The structure and details of the layers are shown in Table 4.6.

Table 4.6

RTNEPH LAYERS FOR RAOB CLOUD LAYER DETERMINATION

Layer	Height ft (m)	Pressure Level (mb)	Thickness ft (m)
	Surface		
1			150 (46)
	150 (46) AGL		
2			150 (46)
	300 (91) AGL		
3			300 (92)
	600 (183) AGL		

4			400 (122)
	1000 (305) AGL		
5			1000 (305)
	2000 (610) AGL		
6			1500 (457)
	3500 (1067) AGL/MSL		
7			1500 (457)
	5000 (1524) MSL	850	
8			1500 (4570)
	6500 (1981) MSL	800	
9			3500 (1067)
	10000 (3048) MSL	700	
10			4000 (1219)
	14000 (4267) MSL	600	
11			4000 (1219)
	18000 (5486) MSL	500	
12			4000 (1219)
	22000 (6706) MSL	430	
13			4000 (1219)
	26000 (7925) MSL	360	
14			9000 (2743)
	35000 (10668) MSL	240	
15			20000 (6096)
	55000 (16764) MSL	100	

4.2.2 Missing Data

Where not specified in the database, heights are computed using the hypsometric equation. Temperature-dew point spread values are computed when required according to:

$$T - T_d = 0.285\ (T - 273) + 20.6 \qquad (3)$$

where T is the temperature in Kelvin degrees and T_d is the dew point in Kelvin degrees.

4.2.3 Midpoint Values

Pressure, temperature and temperature-dew point spread are computed for the midpoint of a RTNEPH layer by interpolating between adjacent reported levels. Midpoint values of MSL are computed directly and midpoint values for the terrain-following layers are computed by subtracting the station elevation from the report height.

4.2.4 Condensation Pressure Spread (CPS)

The CPS, defined as the dry-adiabatic pressure change required for a parcel to attain saturation, is computed from the pressure, temperature and temperature-dew point spread for each layer and is used to relate atmospheric moisture content to cloud amount. The uncorrected CPS, C_u, is given as an approximate by Edson (1965):

$$C_u = (T - T_d)_1[-4.9 - 0.93(\frac{P_1}{1000}) - 9.0(\frac{P_1}{1000})^2] \quad (4)$$

where C_u, T, and T_d were defined previously, and P is the pressure at the midpoint of a layer.

4.2.5 Cloud Amount From CPS

Finally, the cloud amount is estimated from a CPS-cloud amount conversion table derived by Edson (1965). Use of the tables requires calculation of an index, I, as follows:

$$I = 0.5\ KC_u + 1.5 \quad (5)$$

where K is a correction factor based on temperature at the midpoint of a layer. Figure 4.3 shows the CPS-cloud amount relation described by Edson. Separate curves are provided for the 850, 700, 500, and 300 mb levels.

4.3 Aircraft Data Processor

The aircraft data processor computes total and layered cloud amounts from various types of validated aircraft reports encoded in the RECCO, ICAO, and USAF aircraft report formats. Three types of coded information are used: flight weather (Table 4.7), flight condition (Table 4.8), and explicit cloud layer data. Total and layered cloud amount decisions are described below.

4.3.1 Total Cloud Amount

The following decisions determine the total cloud cover:

a. If the flight condition is clear (coded 1), the total cloud amount is set to zero percent.

b. If the flight condition is coded 5, 9, or 18, the total cloud amount is set to 100 percent.

c. If flight weather is coded 5, 6, or 7, the total cloud amount is set to 100 percent.

d. If the cloud amount in a reported layer is overcast, the total cloud amount is set to 100 percent.

e. If none of the above are available, the total cloud is set to missing.

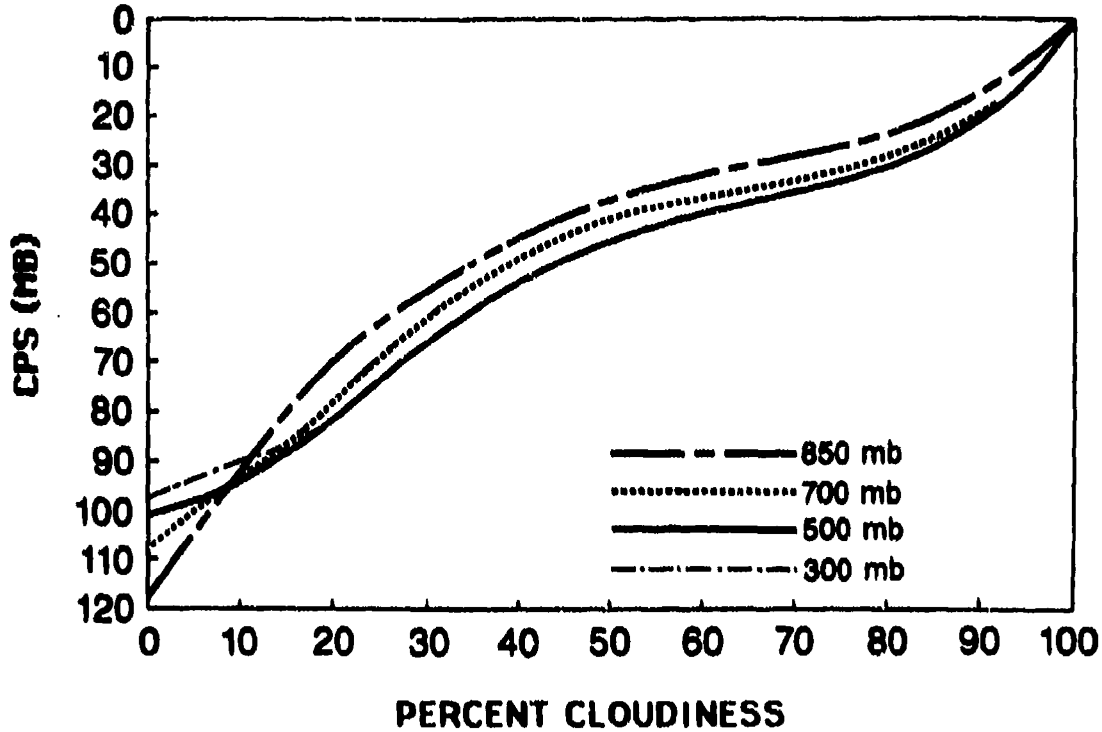


Figure 4.3 Relationship between Condensation Pressure Spread (CPS) and cloud amount for various levels in the atmosphere (from Fye, 1978).

Table 4.7

AIRCRAFT FLIGHT WEATHER

Code Figure	Weather
0	Clear (no clouds at flight level)
1	Partly cloudy (scattered or broken)
2	Continuous layer(s) or cloud(s)
3	Sandstorm, duststorm, or storm of drifting snow
4	Fog, thick dust, or haze
5	Drizzle
6	Rain
7	Snow or rain and snow mixed
8	Shower(s)
9	Thunderstorm(s)
10	Lightning
11	Scattered clouds
12	Broken clouds

4.3.2 Layered Cloud Amounts

Layered cloud data are rather limited in aircraft reports and when available, usually describe conditions only in the vicinity of the aircraft. The following decisions can be made from the flight condition code:

a. If coded 11 or 12, there are no clouds above the flight level.

b. If coded 15 or 16, there are no clouds below the flight level.

c. If clear at flight level, cloud layers are determined directly. If bases or tops are available, but the amount is missing, a cloud amount of 60 percent is assumed. If inconsistencies develop because two or more coded report types are contained in a single aircraft report, specific layered information is given highest priority followed by flight condition reports and flight weather reports.

Table 4.8

AIRCRAFT FLIGHT CONDITION

Code Figure	Flight Condition
0	Total amount of cloud less than 1/8.
1	Total cloud amount at least 1/8, with either 1/8-4/8 above or 1/8-4/8 below, or a combination thereof.
2	Cloud amount more than 4/8 above and 0-4/8 below.
3	Cloud amount 0-4/8 above and more than 4/8 below.
4	Cloud amount more than 4/8 above and more than 4/8 below.
5	Chaotic sky - many undefined layers.

6	In and out of clouds, on instruments 25% of time.
7	In and out of clouds, on instruments 50% of time.
8	In and out of clouds, on instruments 75% of time.
9	In clouds all of the time, continuous instrument flight.
10	Clear (no clouds at any level).
11	Above clouds (tops less than 10000 ft).
12	Above clouds (tops 10000-18000 ft).
13	Above clouds (tops above 18000 ft).
14	Below clouds (bases less than 10000 ft).
15	Below clouds (bases 10000-18000 ft).
16	Below clouds (bases above 18000 ft).
17	Between broken or overcast layers.
18	In clouds.
19	In and out of clouds.

4.4 Decision Tree Processor

The decision tree processor integrates surface, upper air, and aircraft data such that only one report, containing the best information from possible multiple reports, is given per gridpoint. When two or more conventional reports are within a 15 nm radius of an eighth-mesh gridpoint, a single report must be selected or the reports must be integrated to produce a single best report. A final module of this processor sorts the integrated reports to produce an ordered database in RTNEPH eighth-mesh format.

4.4.1 Best Surface Report Selection

A single report may be selected using the following decision criteria:

a. The report with the largest total cloud amount is used.

b. If the reports have identical total cloud amounts, the report with the lowest cloud layer is used.

c. If total cloud cover for the lowest cloud layer are the same, the report received last by RTNEPH is used.

4.4.2 Merging Surface Reports

The most recent report is used and if an overcast layer is reported, any available reports up to 3 hours old are searched for additional cloud information above the overcast layer. Multiple overcast layers are allowed.

4.4.3 Integration of All Conventional Data

The following decisions are made when two or more conventional reports influence a single gridpoint.

a. The process begins with the surface report as the initial report. Surface data are ranked highest below 10000 ft MSL.

b. Data from aircraft reports are integrated into layers above 10000 ft.

c. Upper air reports are stored only for those eighth-mesh gridpoints at which there are no surface or aircraft reports.

4.4.4 Best Reports File

The final function of the decision tree processor is the sorting and storage of the reports in the Best Reports File. This file is updated hourly and is used by the Merge Processor where it is merged with satellite data and the current RTNEPH analysis.

SECTION 5. SATELLITE PROCESSOR

The Satellite Processor, by analyzing satellite data, provides the predominant data source for the RTNEPH. Unlike conventional data, satellite data isn't constrained by uneven distribution, sparcity over remote land areas, or by virtual absence over ocean areas. With two polar-orbiting satellites, for example, virtually every data point is assured of being updated four times a day; grid points near the poles get updates virtually continuously because of the overlap of the orbit swaths (Figure 5.1). The RTNEPH processing software and algorithms can handle data from up to four satellites as long as the data have been mapped into the Satellite Global Data Base (SGDB). However, since its implementation in 1983, the RTNEPH has been primarily limited to processing data from two polar-orbiting satellites due mostly to computer hardware and satellite ingest restrictions.

5.1 General Processing

The basic principles for determining cloud cover characteristics from satellite data are fairly straightforward, but require an extensive amount of supporting data. This, however, is a reasonable tradeoff considering the amount of information to be derived from the satellite data.

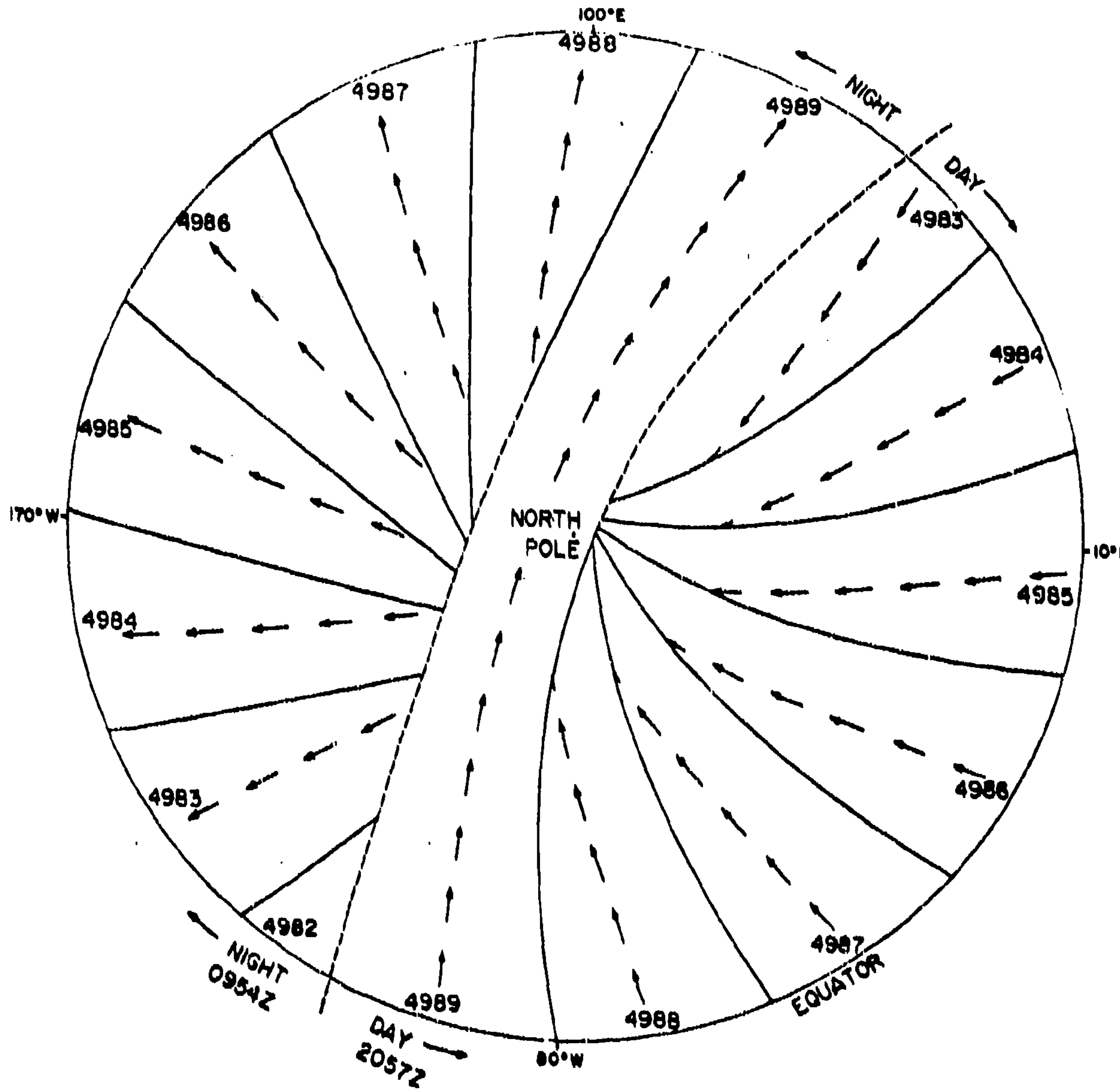
5.1.1 Underlying Principles

Currently processed meteorological satellite data consists of visual and infrared data. In general, darker, or less bright, visual data are associated with cloud-free land or ocean areas. Likewise, lighter or brighter visual data are associated with clouds but, unfortunately, may also be associated with snow, sunglint areas and highly reflective terrain such as deserts, salt flats, or dry lake beds.

Infrared data, on the other hand, represents temperature in terms of brightness. Figure 5.2 shows some general comparisons of temperatures and types of terrain or clouds. For purposes of the RTNEPH, brighter infrared measurements indicate colder temperatures (inverted from the normal sensor standard of colder temperatures represented by lower brightness values, which indicate lower radiated energy). Although both visual and infrared data provide brightness values indicating amounts of reflected (visual) or radiated (infrared) energy, the determination of cloud cover requires a comparison of the sensed values with expected background values. For visual data, the background is a variation of surface albedo; for infrared data, the background is the surface temperature. For cloud cover determination the basic rule then becomes: for visual data, if the sensed values are brighter than the expected background brightness, then clouds are present; for infrared data, if the sensed values are colder than the expected surface temperature by a given amount, then clouds are present.

5.1.2 Inputs and Outputs

The variety of input data and the resultant outputs are shown in Figure 5.3. Specifically, the input data are:



INFRARED SATELLITE GLOBAL DATA BASE

11 June 1982
NORTHERN HEMISPHERE

— — NOAA-7 SUBTRACKS
——— ORBITAL SWATH BOUNDARIES
- - - - - DAY/NIGHT BOUNDARY

Figure 5.1 An example of how data is stored into the SGDB for a single satellite. Note how new data overwrites the old data. Note also that in practice, two DMSP satellites are used rather than the one NOAA shown here.

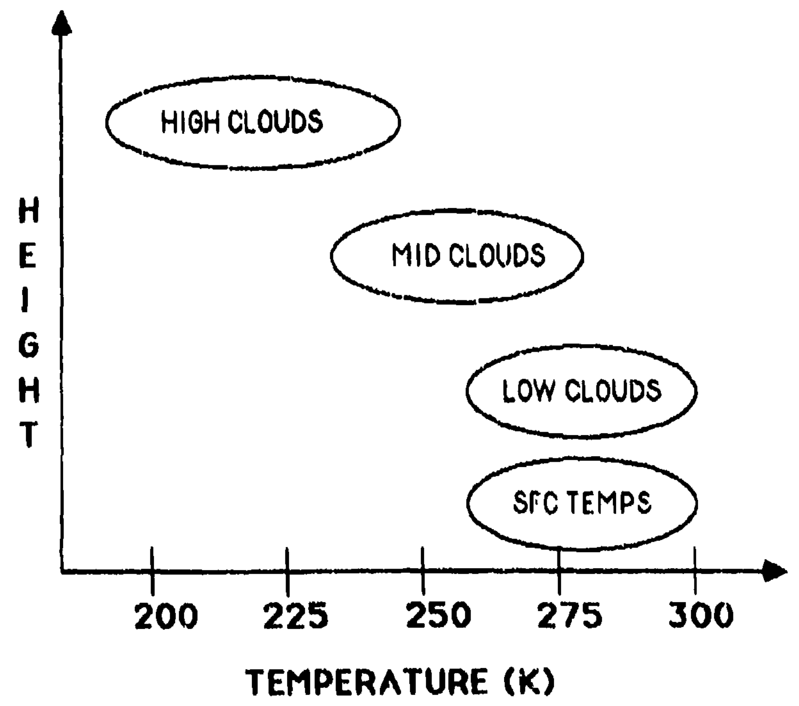


FIGURE 5.2 Relationship between infrared-determined temperatures and cloud and surface temperature. The ovals give an approximate range of temperature for each parameter.

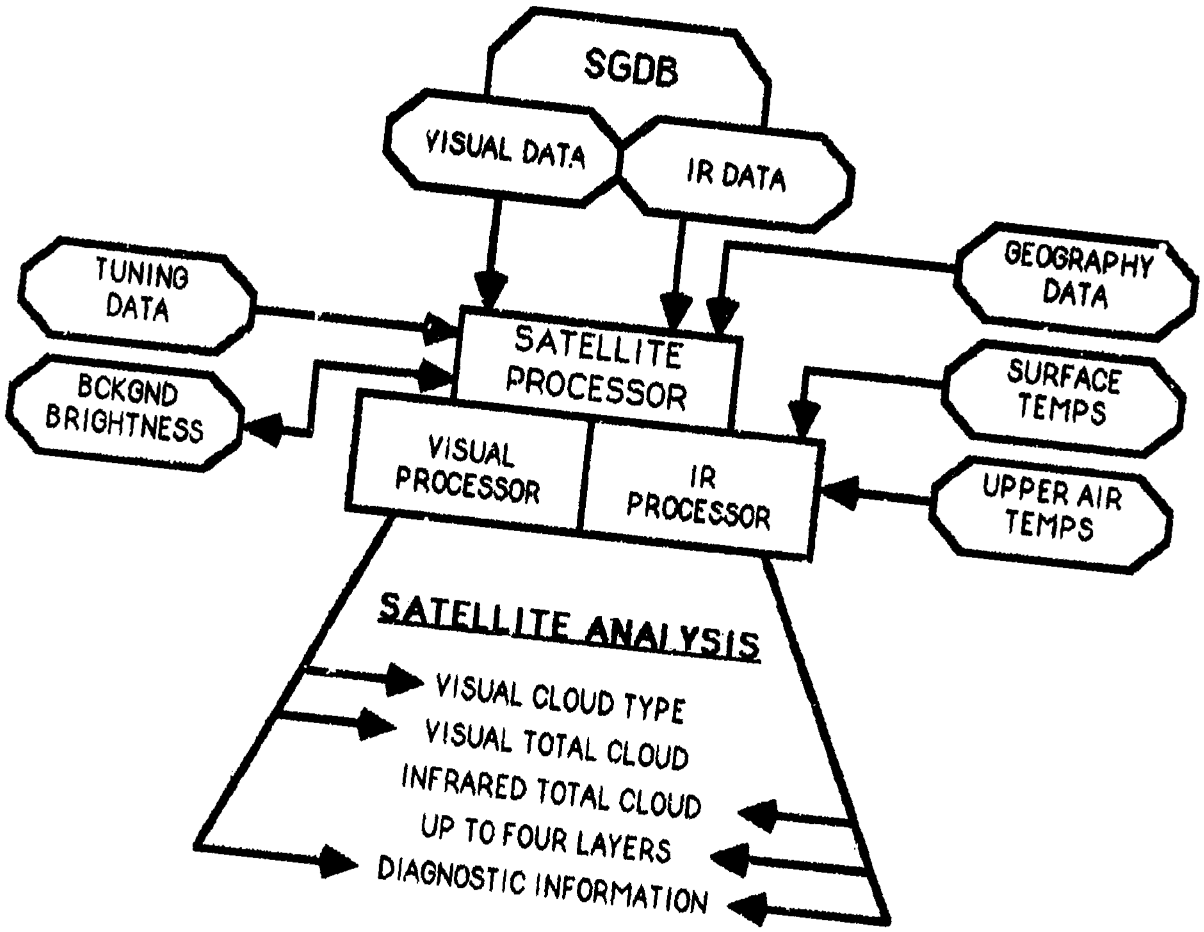


Figure 5.3 The input data and resultant outputs of the RTNEPH Satellite Processor.

a. The Satellite Global Data Base, containing visual and infrared data on an approximately 3 nm by 3 nm basis; the data are represented by grayshades.

b. Tuning parameters, such as grayshade-to-temperature conversion tables, which will be discussed in more detail in the visual and infrared processing descriptions.

c. Terrain heights and geography types. Terrain heights are used to estimate cloud layer tops and bases. Geography types (specifically land, water, coast or ice) are used to insert variations in the cloud determination algorithms.

d. Background brightness fields provide the background against which visual data will be compared to determine cloud cover characteristics. Note that not only are the background brightness fields an input to the processing, but are also an output as the new visual satellite data are used to update the brightness values. We'll discuss this automatic updating later.

e. Surface temperatures (see Fye, 1978 for a description of the surface temperature model) provide the background against which infrared data will be compared to determine cloud cover characteristics.

f. Upper air temperatures are used to define the tops of infrared-determined cloud layers.

The two sets of output data are the updated background brightness data and the satellite analysis. The satellite analysis is an analysis based solely on the interpretation of the newly processed satellite data. The specific contents of this intermediate, satellite data-only analysis are:

a. Visual data total cloud.

b. Visual data cloud type.

c. Infrared data total cloud.

d. Infrared layer amounts and types.

e. Diagnostic information.

5.1.3 The Histogram Method

The basic method in determining cloud cover is the histogram method which is shown in an example in Figure 5.4. Let's say we have a cloud over a water background as seen in step 1. For simplicity, we'll provide the simple, visual data case only. When seen from a meteorological satellite, the conditions in a (approximately) 25 nm by 25 nm nephanalysis gridpoint would appear as in step 2. Step 3 shows an array of the visual brightness values for the (approximately) 3 nm by 3 nm pixel grayshade values from the SGDB. Step 4 shows the resultant histogram for the frequency of occurrence for the possible grayshades. After the histogram is formed, the expected background brightness, here a 5 for a water background, is compared to the histogram and

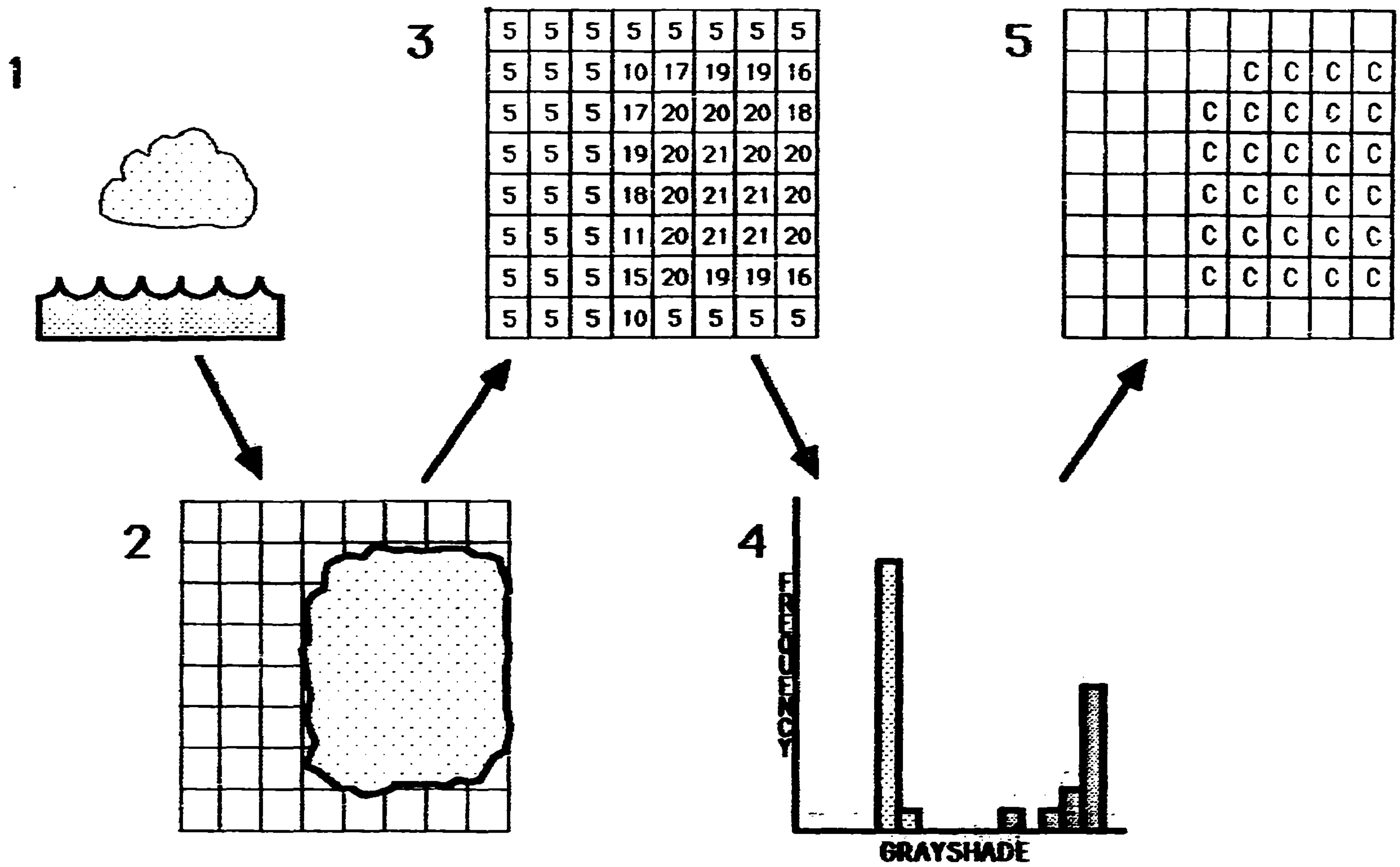


Figure 5.4 Pictorial example of how clouds are determined by the Satellite Processor. Step 1 shows a cloud covering part of a 25 nm grid point. Step 2 shows how the cloud would look overlayed on the 25 nm gridpoint which is divided into an 8 bx 8 array. Step 3 shows the grayshade values the sensor detects. Step 4 shows the histogram built from Step 3. Step 5 shows the cloudy pixels.

all pixels with values brighter than the expected background are considered cloudy pixels. The resultant cloud/no cloud decision array for the pixels is shown in step 5. In this example, we would end up with a 41 percent (26/64, rounded up) cloud cover.

With the infrared processor, the histogram method is a little more complex, but the basic principle of the histogram remains essentially the same. The pixel array for a nephanalysis grid point is formed, a histogram of the grayshades is developed, all pixels brighter than the expected background brightness for visual data, or colder than the surface temperature for infrared data, are considered cloud-covered.

5.1.4. General Processing Flow

Because the input databases are of varying resolution and enter the processing at varying times, a general description of the flow is presented, especially as the flow is related to the resolution and content of several of the input and supporting databases. Figure 5.5 should be referred to during this discussion.

As noted earlier, the coarsest breakdown of the RTNEPH database is the nephanalysis box, with each hemisphere subdivided into an 8 x 8 array of nephanalysis boxes. In turn, each of these nephanalysis boxes is subdivided into an 8 x 8 array of "whole-mesh boxes," and represent the coarsest grid resolution of AFGWC's databases. When the satellite data are processed, the flow is from nephanalysis box to nephanalysis box for consideration with the real decision for processing being decided for each whole-mesh box: if new satellite data are contained with the whole-mesh box, then the box will be processed. The whole-mesh box also represents the granularity of the upper air temperature databases. A single temperature value is assigned to the center point of the box and is considered valid for the whole box, approximately a 200 nm by 200 nm area.

Once a whole-mesh box has been considered for processing, there could still be large areas within the box which don't have new satellite data for processing. The use of quarter-mesh boxes solves this problem. Unprocessed satellite data is retrieved from the SGDB for a quarter-mesh box; each whole-mesh box is, as expected, a 4 by 4 array of quarter-mesh boxes. SGDB look angles, valid times, and satellite identifier are on a quarter-mesh basis and the actual satellite data processing is performed on the whole quarter-mesh box if the box is considered acceptable for processing. After the quarter-mesh box processing decision is made, each eighth-mesh box, the finest unit of the RTNEPH database, is processed by use of the histogram method and the resultant cloud parameters are derived for each of the eighth-mesh boxes.

5.2 Visual Data Processing

Before visual data can be processed, several acceptability checks are made on the data as shown in Figure 5.6. The satellite identifier, valid time and daylight flag are extracted from the information for a particular quarter-mesh

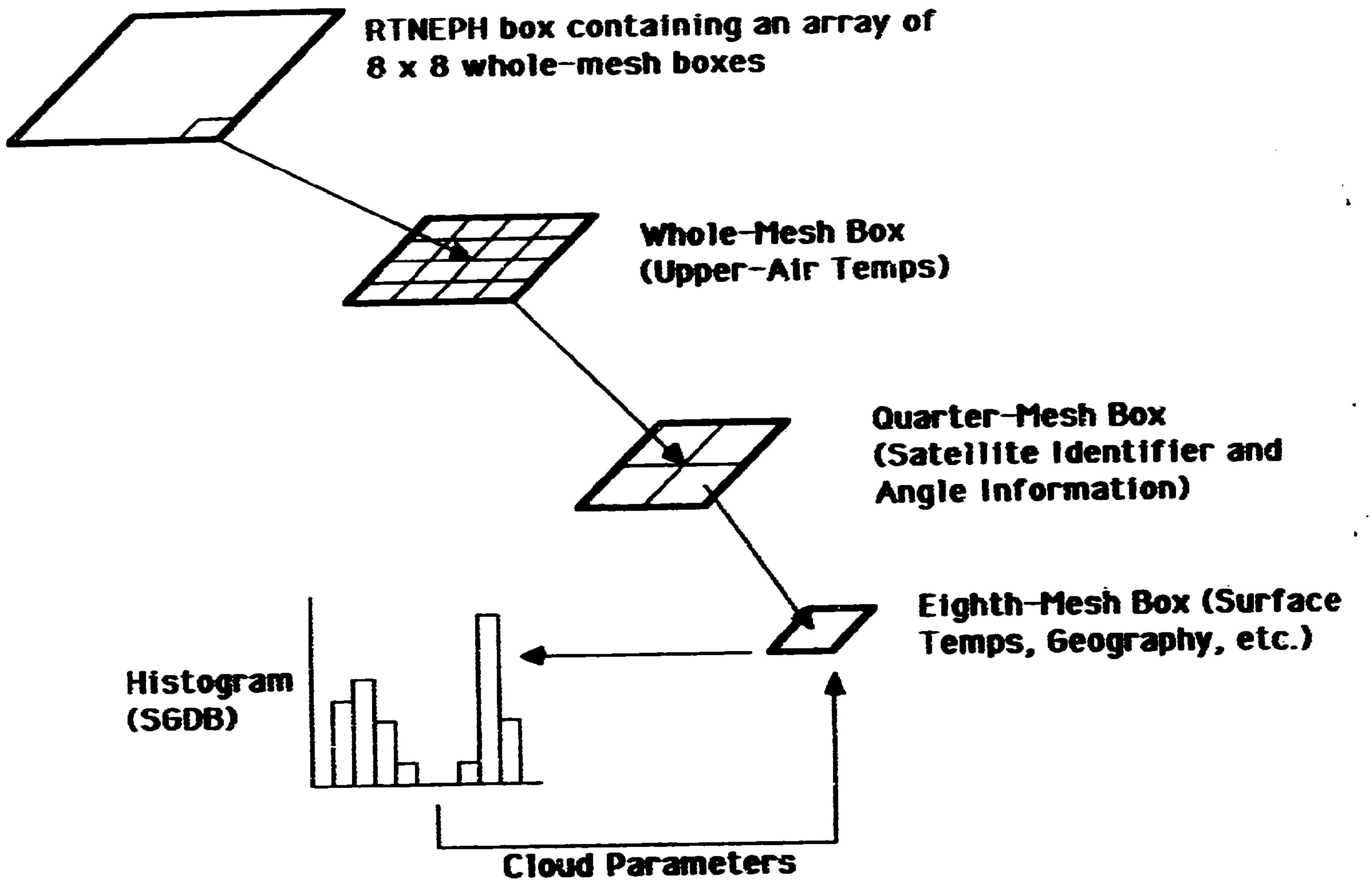


Figure 5.5 The general processing flow of data in the Satellite Processor. Note how the Satellite Processor mixes data from differing resolutions to produce the 1/8th-mesh analysis.

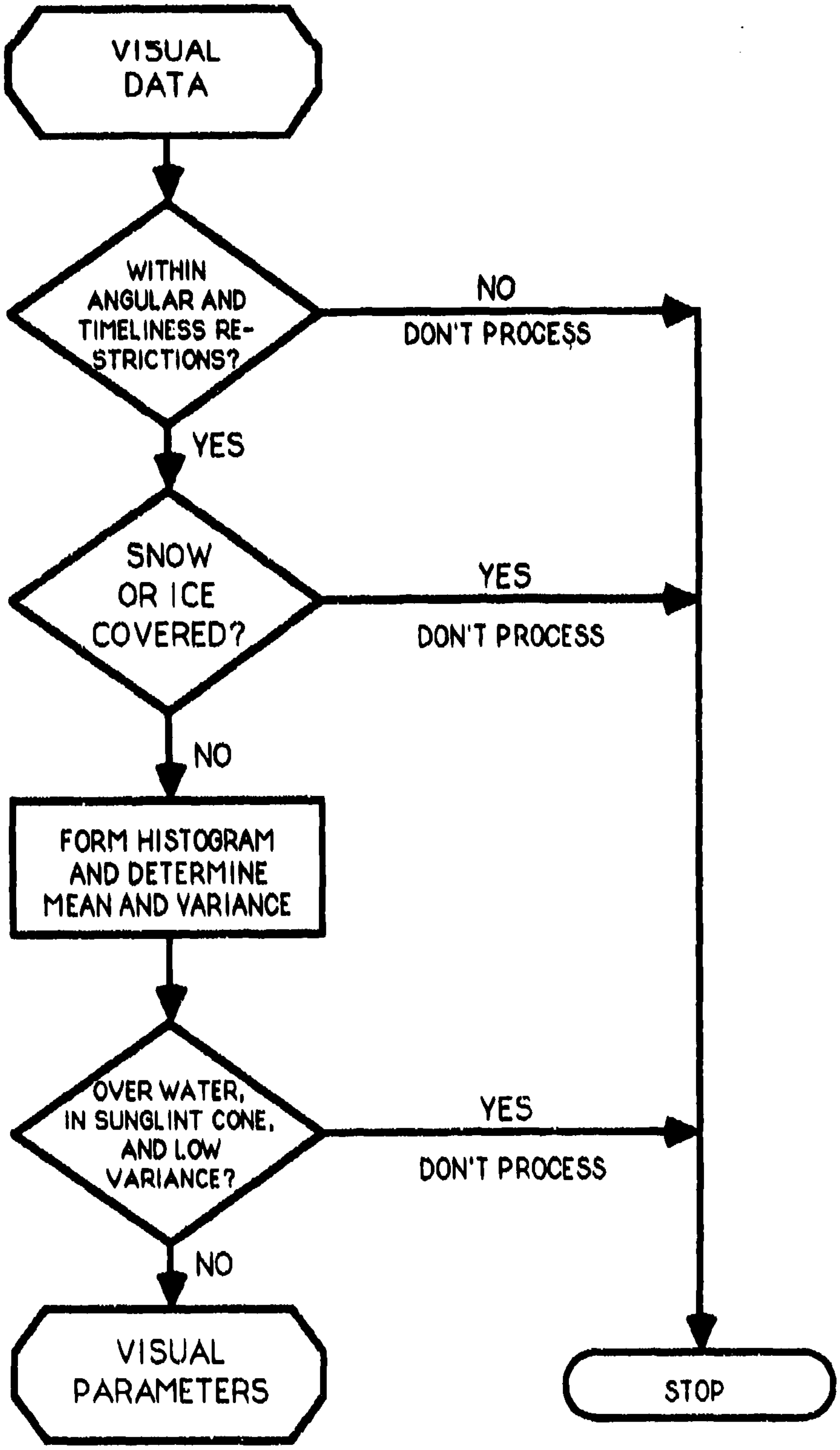


Figure 5.6 The visual data processing flow. Note the many restrictions placed on visual data which can limit its usefulness.

box. These items are used to point to specific locations in look-up tables so the unprocessed satellite data in the quarter-mesh box can be considered for processing. To be processed, the satellite data must pass three criteria:

a. The quarter-mesh box zenith angle must be less than a constraining value derived from lookup tables. These lookup tables are in the tuning parameters database for the Satellite Processor and can be adjusted.

b. The satellite look angle must be less than or equal to a constraining value also derived from lookup tables. These tables are also in the tuning database.

c. The quarter-mesh box data must be sufficiently newer than satellite data already processed, a value from the lookup table presently set at 70 minutes.

After these criteria have been satisfied, the visual data is processed only if the point meets two additional criteria:

a. The point must not be in the sunglint cone and the variance of the brightness values is below a threshold value. The sunglint cone represents the area of a satellite swath where the surface brightness would be great enough to be mistaken for bright clouds. This is especially a problem over water areas. The variance of the visual brightness values is computed and if large enough, clouds are assumed to be present and the visual data is used.

b. The background brightness is not so bright as to be mistaken for clouds in a visual analysis. Because of this snow- and ice-covered grid points aren't processed by the visual processor. Snow covered points are determined by the AFGWC snow analysis model (Hall, 1986) while ice points are retrieved from the geography database.

5.2.1 Visual Cloud Cover Determination

The only parameter we can specifically determine from visual data alone is total cloud. To do this, the Satellite Processor builds the histogram for the visual data, applies a cutoff or threshold brightness value, B, above which pixels are considered cloudy, and determines how many pixels are indeed cloudy. The cutoff is a database-defined value above the grayshade of the background (the background brightness value) (Figure 5.7). B is a function of the specific satellite and background brightness grayshade and accounts for the variability of the 3 nm pixel data within the 25 nm grid point.

5.3 Infrared Data Processing.

Infrared data processing is similar to visual data processing under the general method of forming a histogram of grayshades, selecting a cutoff to differentiate cloudy from clear pixels, and determining the resultant cloud parameters. Just as the visual data was processed under the philosophy of any pixels brighter than the expected background were considered cloudy, for infrared data, any pixels colder than the expected background are considered cloudy.

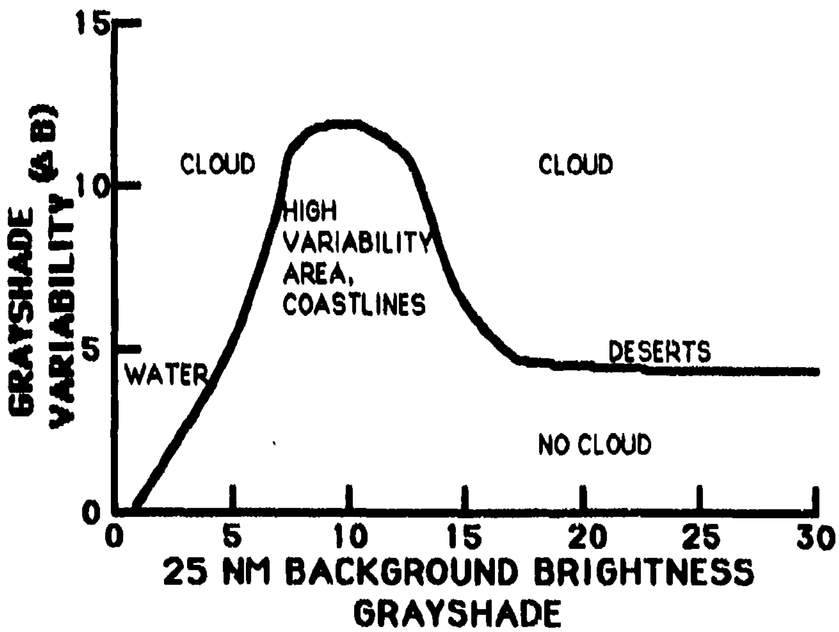


Figure 5.7. Generalized Grayshade Variance Curve as a function of 25 NM Background Brightness Grayshades. This curve is the basis of the cloud/no cloud decisions made in the visual satellite processor. The high amplitude area corresponds to coastal and other high-variability terrain features (from Fye, 1978).

Infrared processing, however, is complicated by the additional requirement that layers must also be determined. As a result, the histogram approach becomes more complex.

5.3.1 Infrared Data Processing Flow

The processing of infrared data depends on a variety of inputs and a processing flow as shown in Figure 5.8. Just as with the visual data, the infrared data must meet several criteria to be processed -- namely the data, based on zenith angle, look angle and timeliness constraints as defined in the tuning parameter database.

5.3.2 Infrared Initialization

Initialization of the infrared processing is relatively straightforward, most of the parameters (the pixel grayshade array, the zenith and look angles, the geography type and the surface height) are read in directly. The expected surface temperature (determination of infrared background) is derived from three inputs: the current analysis, the previous (3 hours old) analysis, and the 3-hour forecast, as shown in Figure 5.9.

5.3.3 Cloud Determination

The cloud determination process flow for each gridpoint is shown in Figure 5.10 beginning with the histogram and ending with the cloud analysis.

In step 1, clusters are located within the histogram. Clusters are initial groupings of histogram entries formed under the following rules:

a. A cluster begins whenever a non-zero grayshade histogram entry follows a zero entry, or whenever a non-zero value follows a cluster end.

b. A cluster ends when a zero valued histogram entry is encountered, or whenever the slope of the histogram goes from decreasing to increasing.

In step 2, clusters are combined together to form modes. Modes are groups of clusters with a sufficient number of pixels and eventually translate into cloud layers.

In step 3, the coldest mode temperatures are found. Corrections are made to these mode temperatures to account for atmospheric attenuation and for instrument variation. These corrections consist of:

a. A bias correction curve. This is an empirical correction obtained by correlating the surface temperature with the infrared sensed temperature in known clear air areas. This curve may be adjusted upon insertion of data from a new meteorological satellite into the SGDB or as needed based on routine quality control of the interpretation and is in lookup table format in the tuning database.

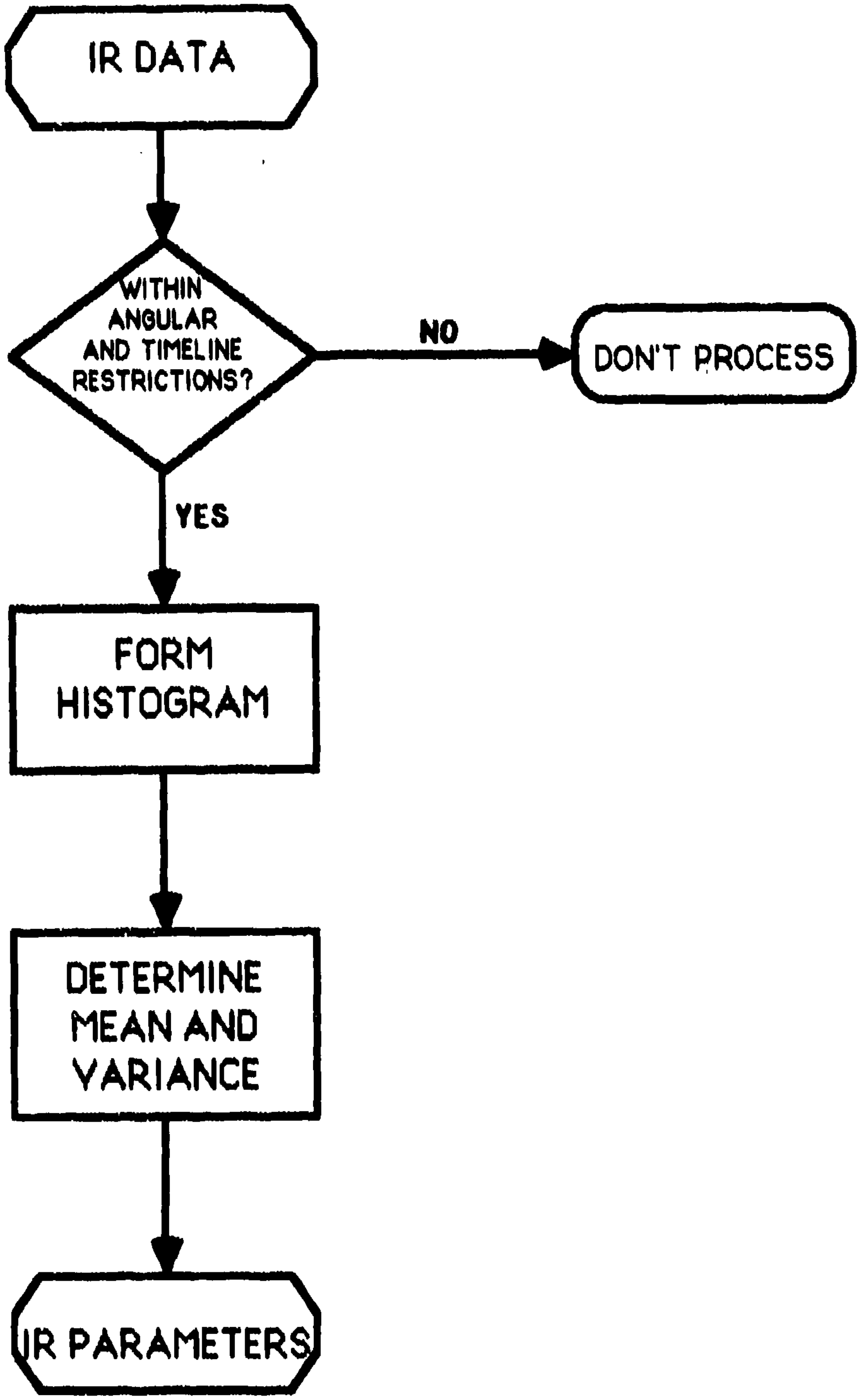


Figure 5.8 The infrared data processing flow.

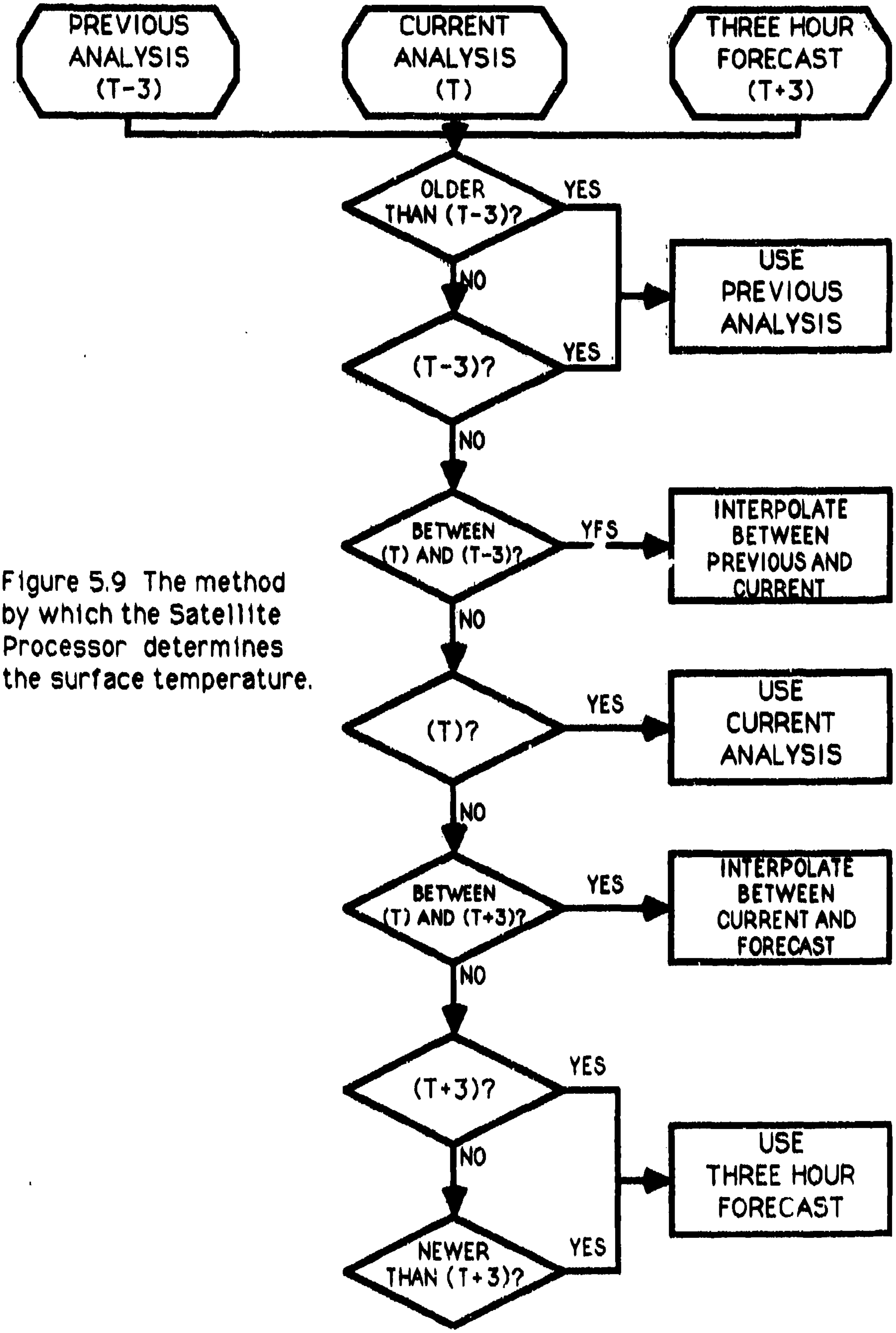


Figure 5.9 The method by which the Satellite Processor determines the surface temperature.

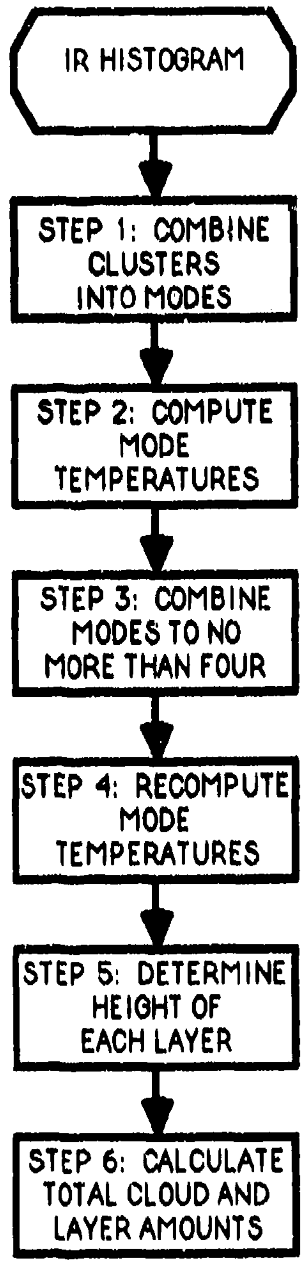


Figure 5.10 The steps used by the infrared portion of the satellite processor to calculate the cloud parameters.

b. Zenith and look angle corrections. These corrections account for variations in the satellite track and for limb darkening at high look angles.

c. Tropical moisture corrections. This correction accounts for higher water vapor attenuation in the tropics. The northern/southern boundary of the "tropics" range from 23° in the winter to 32.5° in the summer.

d. Tuning factors. This is an empirical correction applied to a localized area to slightly raise or lower the modal temperature. These factors are adjusted as frequently as necessary.

In step 4, if there are more than four modes, then they are recombined until only four are left. Then the mode temperatures are recalculated as in step 3.

In step 5, the heights of each layer (mode) is computed by using the upper air temperatures and heights at standard levels. If a temperature doesn't correspond exactly to an upper air temperature, then it is found through interpolation.

In step 6, the total cloud and layer amounts are computed. Total cloud is simply the amount of cloud-covered pixels within all of the modes divided by 64. Similarly, the layered amounts are the total amount of cloud-covered pixels within the specific mode divided by 64.

5.3.4 Layer Statistics

Early in the cycle the mean and variance for the full 8 x 8 eighth-mesh array are calculated. These same parameters are calculated for each of the modes, equivalently each of the layers, so that cloud layer amounts and types can be determined. The Satellite Processor uses standard mean and variance formulas.

5.4 Cloud Type Determination

The layer clouds can be identified as no type in the case of clear conditions, one of the ten types (Table 4.5) previously listed, or as an unknown type. The typing algorithm for the cloud layer types is dependent on the availability of visual and infrared data as well as on the expected values of mean grayshade and grayshade variance. The final decision of the cloud type depends on the visual data index, an infrared data index and a cloud level index. This decision process is shown by the lookup table in Table 5.1.

Table 5.1
INFRARED, VISUAL CLOUD INDEX

VISUAL INDEX	IR INDEX 1 (Cumuliform)		IR INDEX 2 (Stratiform)	
1 (Stratiform)	level=hi	type=CI	level=hi	type=CS
	level=mid	type=AC	level=mid	type=AS
	level=low	type=SC	level=low	type=ST
2 (Cumuliform)	level=hi	type=CI	level=hi	type=CI
	level=mid	type=AC	level=mid	type=AC
	level=low	type=CU	level=low	type=SC

If only visual data are available, the allowable cloud types are no cloud (for clear conditions), cumulonimbus or unknown. If visual clouds are present, the type is assumed to be unknown unless the cumulonimbus (CB) criteria are satisfied:

a. The mean visual grayshade in greater than the CB brightness threshold for the specific meteorological satellite.

b. The visual data variance is less than or equal to the CB variance threshold for the specific meteorological satellite.

The basic principle for determining the type is that the more bright and uniform the visual data are, the more likely that the cloud type is cumulonimbus. When only visual data are available, the lookup table is not used at all.

If only infrared data are available, the lookup table (Table 5.1) is used. The visual index is set to 1; the infrared index is 2 (stratiform) if the infrared layer's variance is less than or equal to a (level-based, satellite specific) variance threshold and 1 (cumuliform)

otherwise; the level is based on whether the top of the layer is in the low, middle or high range. The one exception to using the lookup table is when CBs are being evaluated; if the top of the layer is above 5486 meters and the infrared variance is less than or equal to an infrared CB threshold, then the cloud type is cumulonimbus. Again the basic principle for cloud typing is the more variable the infrared data are, the more likely that cumuliform clouds are being detected.

If both infrared and visual data are available, the cloud typing becomes slightly more complex. First, the Satellite Processor determines the visual index. The visual index is determined in a manner similar to the IR index except that visual brightness variance is used. It is 1 for stratiform clouds and 2 for cumuliform clouds. Then the infrared index is found in a similar manner. Once this is accomplished, the cloud type may be found by using the lookup table (Table 5.1). As with the infrared method, the Satellite Processor uses the same check for determining CBs.

5.5 Merging Data into Satellite Analysis

When the satellite analysis is completed, for each eighth-mesh grid point, the following parameters have been determined:

a. Data mix (infrared, visual or both).

b. Visual cloud type (0, 1, or 25).

c. Visual total cloud.

d. Infrared total cloud.

e. Data time.

f. Visual histogram grayshade variance.

g Visual histogram mean grayshade.

h. Infrared histogram grayshade variance.

i. For each layer, the height of the top, the amount and the type.

j. The difference between the surface and mode's infrared (coldest criteria) temperature.

k. Diagnostic information.

These parameters, along with a comparable analysis from the Conventional Processor and the existing nephanalysis, will be merged in the Merge Processor to produce the new analysis.

5.6 Updating Background Brightness Fields

The interpretation of clouds, especially from visual data, is extremely dependent on the background brightness fields, but these values change due to sun angle changes, reflectivity changes, snow cover changes, etc., and must have a way of being updated. The method for updating is to compare the sensed brightness to the expected background brightness and to let the background brightness be adjusted so that they approach the new sensed values without straying too far from the current values.

Before the brightness values are updated, they must pass two sets of conditions - effectively a set of acceptability conditions and a set of threshold conditions. To be considered acceptable for updating, the grid point must:

a. Be a land or coastal point,

b. Have visual and infrared data,

c. Not be a snow-covered point, and

d. Not be in the sunglint cone.

Those criteria assure that clouds, snow, or sunglint don't affect the updating process. If the grid point has passed these acceptance criteria, then several threshold criteria are considered. These criteria are based on several tuning parameters which can be adjusted by personnel performing quality control of the nephanalysis. To be updated, a grid point must pass all the following thresholds tests:

a. Analyzed visual total cloud must be less than or equal to a threshold value for the total visual cloud (i.e., if the grid point is relatively uncloudy, visually).

b. There's no infrared determined cloud or the analyzed infrared total cloud is less than or equal to a threshold value for total infrared cloud.

c. The visual data zenith angle is less than or equal to a threshold value for the visual zenith angle.

d. The mean grayshade for the pixels must be less than or equal to a mean grayshade threshold.

e. The difference between the mean grayshade and the background brightness value must be less than or equal to a maximum allowable difference (i.e., don't update if the analyzed mean grayshade and existing background brightness value are too different).

Having passed these acceptance and threshold checks, the grid point's background brightness value will be updated. As part of the updating, several parameters are incorporated into the updating, namely:

a. A maximum allowable change

b. An upper limit on a changed brightness value

c. A lower limit on a changed brightness value

The updating algorithm then becomes:

a. If the mean analyzed grayshade is greater than or equal to the background brightness, then the new background brightness = minimum of upper limit (b above) and background brightness + 1/2 (mean - background brightness).

b. If the mean analyzed grayshade is less than the background brightness, then the new background brightness = maximum of lower limit (c above) and background brightness - 1/2 (mean - background brightness).

SECTION 6. MERGE PROCESSOR

6.1 Overview

The satellite and conventional processors, as noted earlier, provide global analyses, but only at the grid points where they processed data. The Merge Processor merges these analyses into the existing nephanalysis database. When the Merge Processor completes this incorporation, it provides an updated global nephanalysis database. The merging of this new data not only updates the basic parameters, such as total cloud amount, but also the layer source data and diagnostic information.

6.1.1 Inputs

The inputs, as shown in Figure 6.1, are fairly straightforward. The current persistence nephanalysis database serves as the starting point; the conventional analysis will provide input at only those grid points where conventional data were actually available; the satellite analysis provides the analysis over those areas where meteorological satellite data were available. If we consider one box, as shown in Figure 6.2, we would have the full box analysis for a starting point, the grid points where conventional reports were analyzed, and the area where newly processed satellite data were available. The geography fields also are input, but are used to aid in decisions at individual grid points rather than supplying actual input data.

6.1.2 General Process Flow

The general process is to start with the current analysis and bring in a new input such as the conventional or satellite analysis, and incorporate the new data as processed. Figure 6.3 shows a more detailed flow of this process. During the merge of this data, decisions are made whether or not to incorporate the new data based on timeliness and data type considerations; these considerations will be discussed in more detail later. Additionally, the merge process will reconcile conflicts between conventional and satellite data. When the Merge Processor is finished, a complete, updated database will exist for any applications program.

6.1.3 Modifiable Parameters

Like the Satellite Processor, the Merge Processor allows some flexibility by using easily modified tuning parameters. The application of the specific parameters will be discussed in later sections.

6.2 Baseline Analysis

The baseline, or starting point, for the Merge Processor is the existing analysis database. In general, whenever new data aren't available, the Merge Processor will persist the original analysis. Although this can cause the data at some grid points, particularly near the equator, to become increasingly older, this can be identified by querying the data valid times.

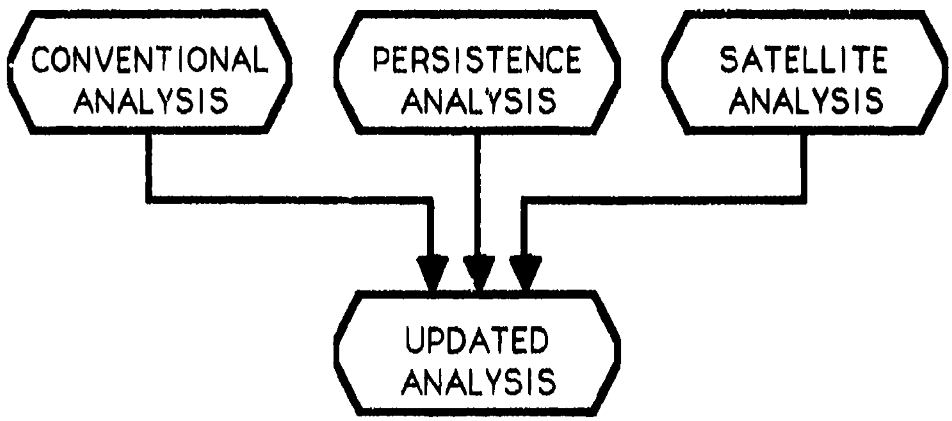


Figure 6.1 The major inputs for the Merge Processor.

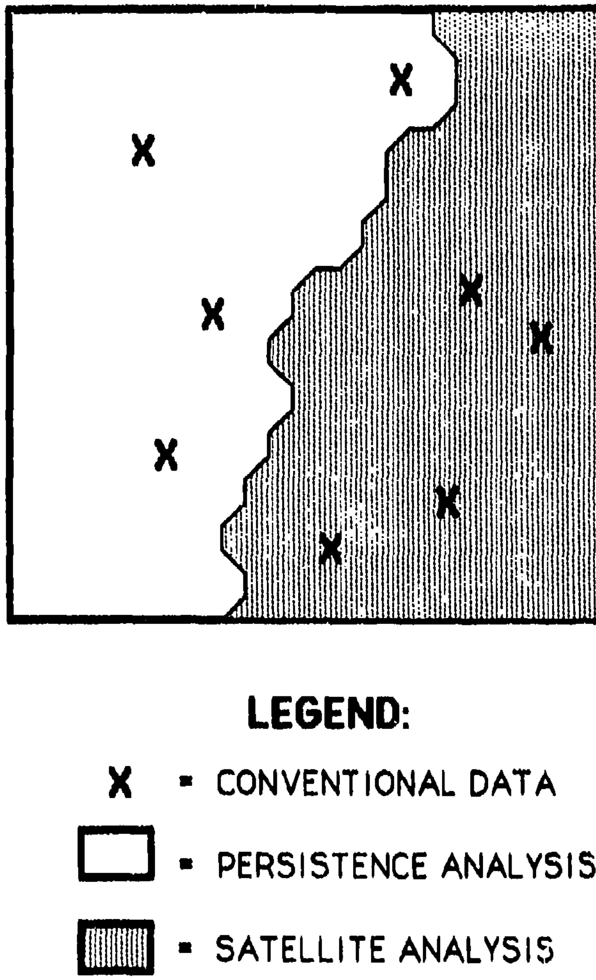


Figure 6.2 An example of how a particular RTNEPH box of data may be merged. The area where new satellite data is can have satellite data and conventional data to add to the persistence analysis. Where there is only conventional data, then that data is available to update the persistence analysis. If only persistence data is available, it is persisted.

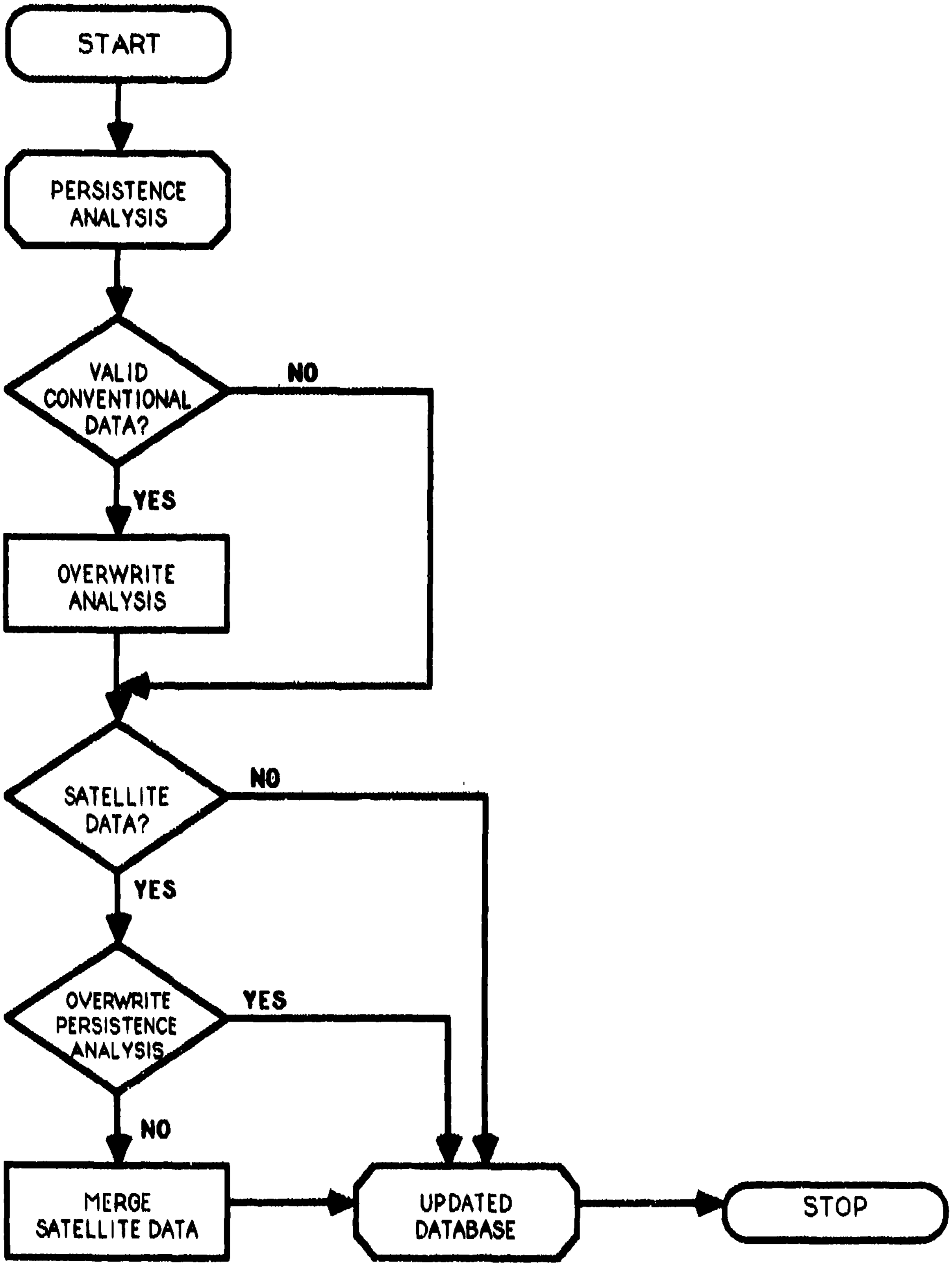


Figure 6.3 The process flow of the Merge Processor.

6.3 Merging Conventional Data

The conventional analysis, as noted earlier, provides information only at those grid points where a conventional report was available for processing. The Merge Processor will both reduce and increase the influence of this data. The reduction occurs when it excludes data from consideration because the data failed certain timeliness criteria. The increased influence occurs when conventional data are "spread." Data spreading, discussed in more detail later, refers to the use of a conventional data report at grid points other than the specific grid point to which the report was assigned. This process allows a greater spatial use of conventional data when no other data are available. This spreading depends on the assumption that conditions observed by a surface-based observer are most likely representative over a greater area than a single grid point.

6.3.1 Timeliness and Quality Checks

The Merge Processor doesn't just insert the conventional data arbitrarily, but instead requires the data pass some timeliness and quality checks. In the case of merging the conventional data, the only check is whether the conventional data is overwriting a "timely" bogus, with "timely" being a database defined time. (A bogus is a manual modification to the RTNEPH via the Bogus Processor). In effect, the timeliness and quality check is: if the grid point doesn't have the bogus flag set or, if the grid point has been bogused, but the bogus is more than an acceptable (a tuneable parameter) amount of time older than the valid time for the report, <u>then</u> the conventional data will be inserted into the analysis.

If the conventional report has been determined to be sufficiently timely or doesn't overwrite a bogused point, some quality checks and corresponding corrections, if needed, are performed, specifically:

a. Is the total cloud zero with non-zero layers? If so, replace the total cloud with the sum of the layers.

b. Is any layer larger than the total cloud value? If so, replace the layer amount with the total cloud rounded up to the nearest 5 percent.

c. Is the total cloud greater than the sum of the layers? If so, replace the top layer with the total cloud rounded up to the nearest 5 percent.

Although there is no direct check for total cloud greater than zero but with zero-valued layers, this is effectively checked in the third check. However, these errors seldom occur. Although these checks and corrective measures may not be very sophisticated, they reduce the magnitude of the inconsistencies.

By the time the Merge Processor completes quality and timeliness checks, updated grid points contain new values for:

a. Present weather

b. Visibility

c. Total cloud

d. Layers based on conventional data

e. Layer source data (reflecting RAOBs, AIREPs, or surface reports only)

f. Diagnostic entries for:

(1) Best report

(2) Type of best report (RAOB, AIREP, surface report)

(3) "Unset" bogus flag if overwritten

(4) Haze override, if applicable from the Conventional Processor

These new values exist at the particular grid point only, and must then be considered for "spreading".

6.3.2 Determining the Spreading Distance

The spreading distance is based on the principle that a conventional report (i.e., observation from other than a meteorological satellite, usually surface-based) represents an area greater than just one grid point. Also, the higher the cloud layer, the larger the area over which the report can be considered representative. The RTNEPH allows seven spread distances (tunable) based on the following seven criteria:

a. Lowest base is less than 2000 m

b. Lowest base is between 2000 m and 5000 m

c. Lowest base is greater than 5000 m

d. Grid point is clear

e. Conventional data had missing base

f. Coastal grid point spreading to land points for cumulus type clouds, or,

g. Water grid point spreading to land or coast.

6.3.3 Determining Grid Points To Spread To

Up to now we've developed a set of meteorologically consistent data at a grid point and the array (a set of grid points) to consider for spreading the data. Now we consider each of the grid points in this array. The Merge

Processsor calculates the distance from the particular grid point to the best report grid point. This radial distance will be used whenever a grid point is within the scan radius of more than one best report.

Once the Merge Processor determines the spread radius, it will compare the distance from the best report grid point to the considered grid point, using the following criteria:

a. If the distance is greater than the allowable spread radius, the best report data won't be spread to the considered grid point.

b. If the considered grid point is within the allowable spread radius, several other checks are considered:

(1) If no data have been spread to the point yet, go ahead and spread to that point.

(2) If data have already been spread to the point from a previously considered best report, then:

(a) If the distance from the current best report is greater than from the previously used best report, don't spread.

(b) If the distance from the current best report is less than the previously used best report, spread.

(c) If the distances are equal, yet another set of criteria are considered:

1. The newest of the two best reports is spread to the grid point under consideration.

2. If the two best reports are equally timely, the least cloudy one is used.

3. If the two best reports are equally cloudy, the one with the greatest visibility is used.

4. If no tie breaker arrived by now, just retain the data already spread to the considered grid point!

6.3.4 Spreading the Data

At this point a consistent, complete set of parameters have been determined at the grid point with the best report, and the array of grid points to which these data can be spread have also been determined. One last check is made though, before data are spread to the point. If the point has a bogus "newer" (i.e., by a database defined parameter) than the best report, don't spread to the point.

When the actual spreading of the data is complete, there are still some modifications to the data to be made, namely:

a. If the base of a layer is lower than the terrain at the spreaded grid point, the base is replaced by the terrain height.

b. If the top (as well as the base) is lower than the terrain at the spreaded grid point, don't spread that particular layer to the grid point (this effectively allows stratus not to spread onto high terrain, for example).

Similarly, if some data are still missing, this problem will be adjusted:

a. If the cloud layer type is missing, it will be considered stratus.

b. If the cloud top is missing (a frequent situation when considering surface-based reports) the new (estimated) top of the layer will be

$$\text{top} = \text{base} + \text{thickness}$$

where the thickness is a function of the cloud type as shown in Table 6.1:

Table 6.1
DEFAULT THICKNESSES BY CLOUD TYPE

	Type	Thickness (meters)
(1)	Cumulonimbus	6500
(2)	Stratus	300
(3)	Stratocumulus	1800
(4)	Cumulus	2000
(5)	Altostratus	1000
(6)	Altocumulus	1800
(7)	Nimbostratus	2000
(8)	Cirrus	1000
(9)	Cirrostratus	1800
(10)	Cirrocumulus	2000

If the Merge Processor estimates the layer top, it sets the estimated top flag in the source information for the applicable layer. The diagnostic data will be updated at the spread-to grid point to reflect the diagnostic information at the source point. The only difference is the spread-to grid point will have the spread-to flag set. The valid time of the data at the spread-to grid point will be that of the "best report" which was used for the spreading.

6.4 Merging Satellite Data

The incorporation of conventional data were relatively simple: the decision were generally based only on whether the data considered were newer than data already present. The incorporation of satellite data includes not only time checks for the relative currentness of the data, but also "exception" rules based on the special characteristics of meteorological satellite data, both visual and infrared.

6.4.1 Timeliness and Data "Quality" Checks

As with the conventional data, the timeliness of the satellite data is a major factor in any decision to include the satellite analysis in the final nephanalysis database. The decision rules on a grid point basis, are as follows:

a. If the current analysis includes satellite data and the satellite data under consideration are more than 70 minutes (adjustable) older than the current analysis, then it's assumed the satellite data have already been processed, possibly being the same data as already exists in the analysis. Satellite data failing this check are rejected for processing.

b. If the satellite data are more than a database-specified number of hours newer than the analysis, then the current analysis is deemed to be excessively old and is directly replaced by the satellite data.

c. If the current analysis is older than the satellite data, again by a database specified number of hours, but is not "excessively" older, then lower clouds contained in the current analysis may be retained.

The decision whether the satellite data are to be included is summarized in Figure 6.4.

We're essentially left with three cases to describe further:

a. The satellite data completely overwrite the current analysis.

b. The satellite data are newer than the current analysis, but not so new as to preclude retaining or persisting the low clouds.

c. The satellite data and the current analysis, which contained conventional data, are both "timely".

6.4.2 Satellite Data Incorporated Directly

Recall the satellite analysis has values for visual total cloud and infrared total cloud. The Merge Processor uses these two independent values to determine the analysis values when the satellite data completely overwrite the current analysis. These amounts, plus the type of satellite data considered, are processed as follows:

a. If only infrared data are available, the layers derived from the infrared data are used and the total cloud is the infrared-derived total cloud.

b. If only visual data are available, another decision is applied: if the visual total is zero, the point's data reflect clear conditions; if the visual total is not zero, then the point is left clear and the Merge Processor sets a diagnostic flag to indicate this case.

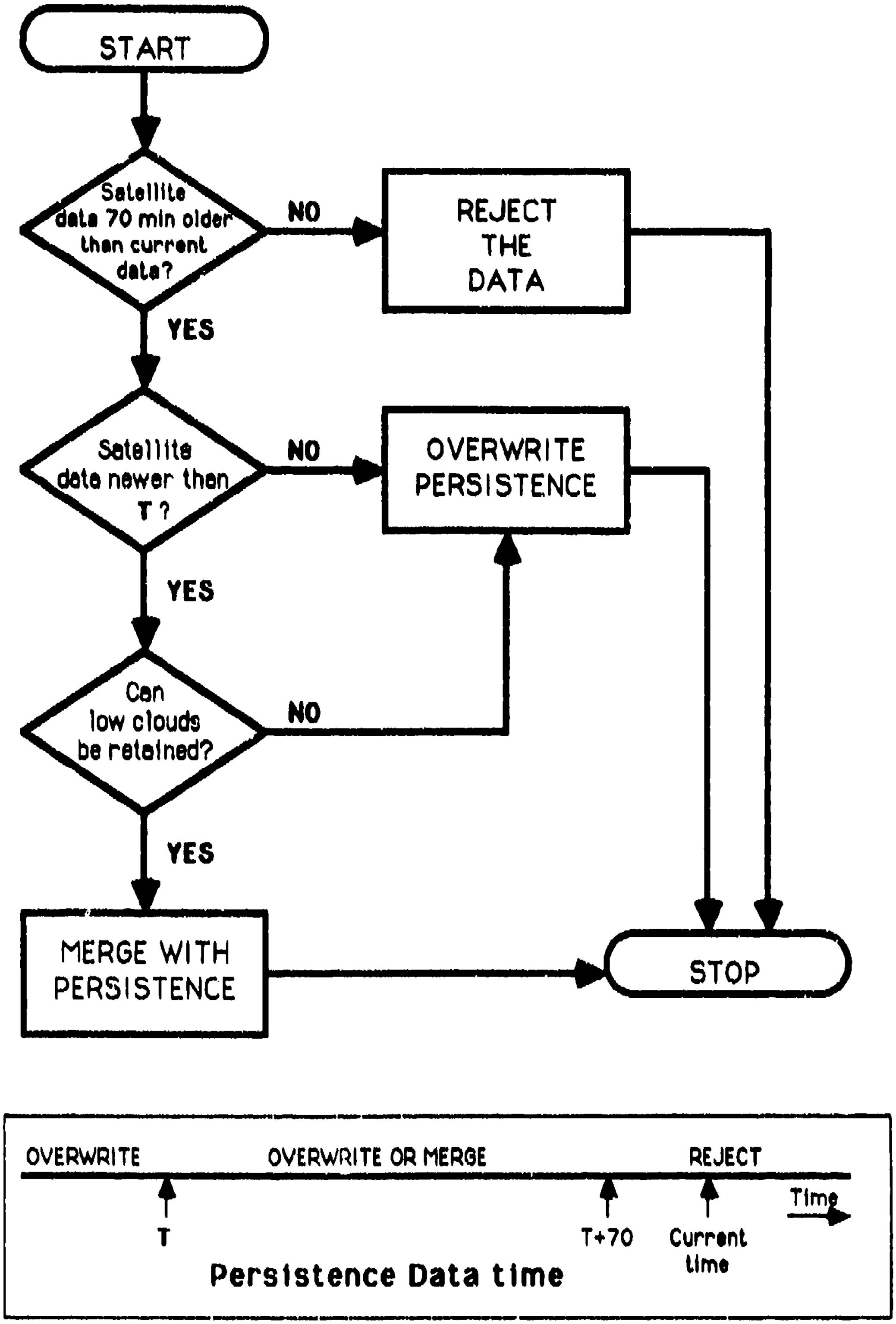


Figure 6.4 The decision tree for using satellite data in the Merge Processor.

c. If both infrared and visual data exist, the Merge Processor uses a new decision tree:

	visual total >0	visual total =0
infrared total >0	store larger total cloud. Add a stratus layer if visual total cloud is "significantly" larger than IR total cloud.[1]	denote high cloud layers as thin[2]
infrared total =0	Form a stratus layer[1]	clear

1 This rule represents the fact that the infrared data often cannot detect low clouds because the temperatures of the stratus top are close to or even warmer than the ground temperature. The characteristics of this formed layer are:

amount = difference between the visual total cloud and the infrared total cloud

type = stratus

base = terrain height + "stratus-base" (database parameter)

top = base + 200 m

Additionally, diagnostic flags for estimated base, estimated top and visual data will be set.

Even this rule, however, has a variation if there are already four layers: the lowest layer amount will be increased so that it is the minimum of "total cloud" and "layer 4 amount plus the difference between the visual and infrared total amounts"; the layer 4 type is incremented by 10 to show a stratus or fog layer when four layers already exist.

2 This rule reflects the fact that thin cirrus will be detected by the infrared sensor, but the visual return may detect no clouds or a cloud layer more like haze than cloud. No correction is made to the cloud thickness; a +1 offset is added to the layer amount.

6.4.2.1 Layer Adjustments

With the above processes complete, the analysis has a set of layers derived from the satellite data. However, each layer amount is the percentage of the view filled by that particular layer (as shown in Figure 6.5) rather than the

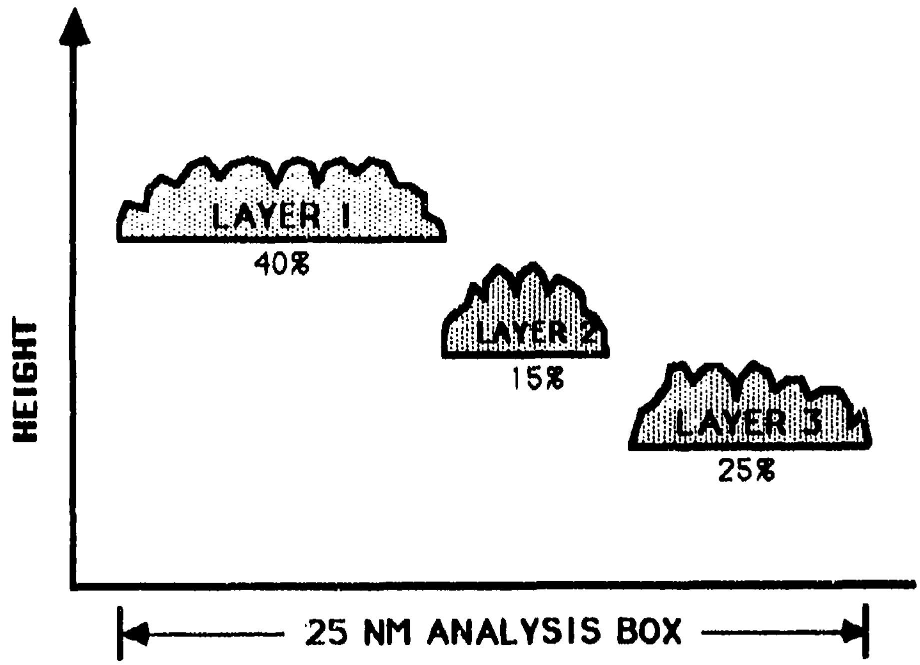


Figure 6.5 Cloud layer amounts before spreading in the Merge Processor.

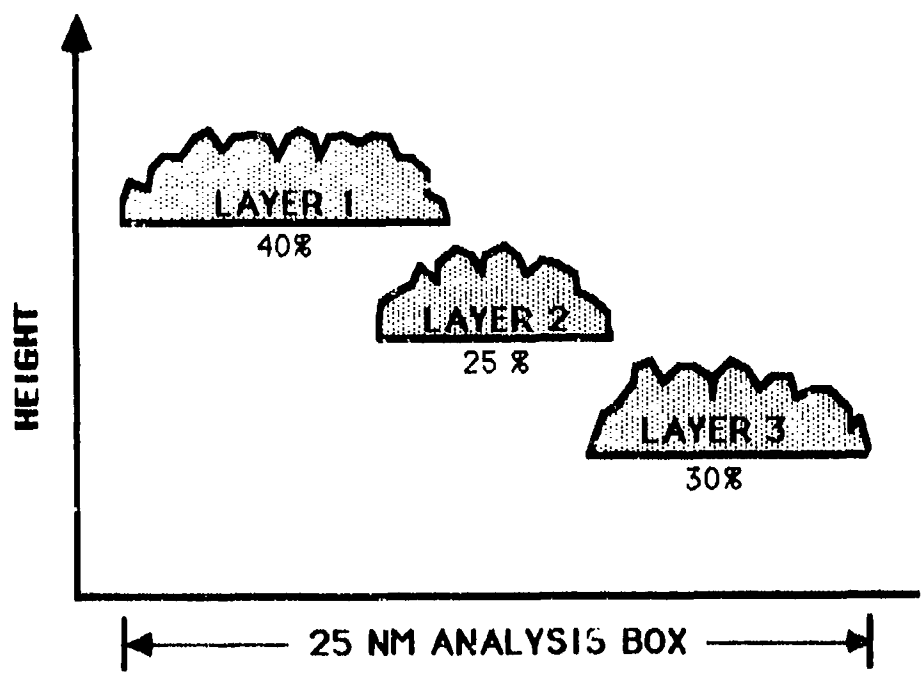


Figure 6.6 Cloud layer amounts after spreading in the Merge Processor.

true layer amount. To calculate the "true" layer amount, it's assumed each layer occupies approximately the same percentage of the total sky as it occupies in the unobscured sky (as shown in Figure 6.6).

6.4.3 Satellite Data Merged Into Analysis

When the persistence analysis is new enough (less than four hours), the Merge Processor must merge satellite data into the persistence analysis instead of overwriting it.

6.4.3.1 Low Cloud Retention

Before the satellite data can be merged, the Merge Processor seeks to eliminate high and middle clouds from the persistence analysis. It will do this if either of the following conditions can be met:

a. If the persistence analysis is at least 70 minutes older than the satellite data, or

b. If there are no satellite layers in the persistence analysis.

Assuming either of the above conditions are met, the Merge Processor will strip high and middle clouds from the persistence analysis. The justification for doing this is that the satellite data is inherently better at detecting higher clouds than low-level clouds. Otherwise, the Merge Processor may lose a low cloud layer that the satellite analysis missed, but the conventional data had detected.

6.4.3.2 Merging Satellite Data with the Analysis

The Merge Processor can now merge the satellite data into the analysis. The merging is rather simple -- the satellite layers are inserted into the database. However, if visual satellite data is the only data source, then it's only used to adjust the total cloud in the persistence analysis since there's no layer information contained in it.

6.4.4 Cloud Layer Adjustment

The internal arrays in the Merge Processor can hold up to eight cloud layers. At this point, layers must be reduced to no more than four layers. If more than four layers exist, the Merge Processor begins looking for compatible layers to merge within a specified scan radius. The scan radius is the distance between the lower layer's top and the higher layer's base. Layers are merged according to their height group and CB clouds are excluded from the merging. If for instance, the distance between a layer of AS and AC was within the scan radius, the two layers would be joined together. This new layer would carry the base of the lower layer, the top of the higher layer, the higher type number (see Table 4.5), and the amount of the layer with the greatest amount unless the sum of the two layers is less than the total cloud value. In that case, the Merge Processor will use the sum of the two layers.

If, after one pass, there are still more than four layers, then the scan radius is incremented and the process repeated. When the Merge Processor finishes the layer merging, the analysis is complete and is stored in the database.

SECTION 7. BOGUS PROCESSOR

7.1 Bogus Processor Concept

As noted in earlier sections, interpretation errors can occur. The most common misinterpretation is due to the difficulties of analyzing fog or stratus, especially over snow-covered backgrounds. To compensate for this, the capability to correct the database after detailed quality control has been provided by the unfortunately named Bogus Processor. This processor allows a database analyst to perform a near real-time correction in conjunction with near real-time quality control. The Bogus Processor can be executed independent of the other processors and is used by the available personnel and computer resources to conduct as much quality control as is desired. Because the Satellite and Merge Processors operate on a quarter orbit by quarter orbit basis, bogusing is also done on a quarter orbit by quarter orbit basis.

7.2 Method

The method of meteorological satellite data input has historically been a function of the hardware available at the Air Force Global Weather Central. In 1987, the procedure was to define the perimeter of the area to be changed by using a cursor on a digitizing table. When AFGWC's new Satellite Data Handling System (SDHS), a system of minicomputers and graphics terminals, becomes operational, the method will be to define the area to be bogused on a graphics terminal. In addition to the perimeter definition, the new cloud parameters are input. Up to ten parameters may be used in the bogused area. However, as will be discussed in more detail later, any inputs will eventually be constrained by the database itself; e.g., a maximum of four layers will be retained at a grid point.

After the perimeter is defined, the grid points on and within this perimeter are determined; these are the grid points at which the input parameters will be processed. The grid points are determined by a variant of the common screen-fill or "paint" programs and warrants no further discussion.

Once the applicable grid points have been determined and the new database parameters input, the continuation of the Bogus Processor depends on the option selected.

7.3 Bogus Options

Three possible bogus options can be applied. The first is to insert new weather and visibility values at a grid point, a rarely used option. The second option, also rare, is to insert a totally new cloud layer by defining a cloud base and top as well as a type and amount. The most frequently used option, the third, is to define a cloud type and amount for the new layer, and to use a set of default values for the base and top. The new data are processed into the database and then, depending on the option selected, inconsistencies are corrected and diagnostic information is updated.

Some constraints on the eventual "appearance" of the database result from two pre-processing activities on the inputs. First, the cloud amounts are usually entered in eighths and converted into percents as shown in Table 7.1.

Table 7.1
CLOUD AMOUNT CONVERSIONS

Cloud Amount (Eighths)	Converted Percent
0	0
1	15
2	25
3	40
4	50
5	65
6	75
7	90
8	100

Likewise, the visibility values are entered in kilometers and encoded as shown in Table 7.2, which represents WMO Code 4377.

Table 7.2
VISIBILITY CONVERSIONS

Input Visibility (km)	Code Value (range)
.1	00 (00)
.1 - 5.0	vis x 10.1 (01-50)
6.0 - 30.0	vis + 50 (56-80)
30 - 70	(vis/5)+74 (80-88)
70 - 89	(89)

These pre-processing conversions, especially the cloud amount conversion, can cause an increased frequency of occurrence of certain values and should be considered whenever any statistical summaries of the nephanalysis database are done.

7.3.1 Weather/Visibility Bogus

Bogusing the present weather and visibility parameters is a straightforward, but infrequently used option. The basic operational flow is to:

a. Replace the database present weather value with the bogused present weather.

b. Replace the database visibility with the bogused visibility.

c. Set the bogus indicator in the diagnostic word.

d. Cancel out the "second weather" indicator in the diagnostic information if the most current data at the grid point were more than four hours old or if weather types 05 (haze) or 40-49 (fog types) were bogused.

The first three steps merely update the database and indicate that the grid point data contain bogused information. The last step is to assure that the primary present weather and the second weather parameters don't both reflect the existence of fog or haze and that the existence of fog or haze is not retained too long in the database (i.e., if present weather is intentionally changed, then fog or haze shouldn't be retained too long). The valid time of the data is not modified to reflect the bogusing, but will continue to reflect the time of the cloud information.

7.3.2 Type/Amount/Base/Top Bogus

Inserting entirely new cloud layers into the database is the primary purpose of bogusing. The most definitive option is to input the full set of layer-defining parameters: cloud type, amount, base and top. This option, although not as straightforward as the visibility/weather option, still can be reduced to a set of basic functions. After the bogus data have been input, several processes occur, namely:

a. Clear out "old" low (middle or high) layers if low (middle or high, respectively) layers are to be inserted.

b. Insert the new set of bogused cloud layers.

c. Sort the new set of layers in descending order with the layer with the highest base being the first layer.

d. Merge layers until no more than four layers remain, calculating new layer parameters for the layers created in this merge process.

e. Recalculate the total cloud amount based on the final (up to four) cloud layers.

f. Update the diagnostic information in the database.

The separate steps warrant further discussion. Before any new layers can be inserted, the Bogus Processor will eliminate any "appropriate" layers in the pre-bogus database. An "appropriate" layer is one in the same grouping (i.e., low, middle or high). For example, if a low cloud type is to be inserted, previously existing low clouds will be eliminated prior to inserting the new low cloud layers. This process can be done only once for each of the low, middle or high groups, on the first insertion; this precludes newly bogused low (or middle or high) layers from eliminating the other bogused layers of that same group otherwise the bogused areas would effectively be restricted to one low, middle or high layer.

The insertion of the new layers is essentially just to put them into an array of layers to be sorted and eventually reduced to at most four layers. As part of this process the bogused bases and tops are encoded to database values (see Table 4.5) and added to the terrain elevation at the point. The bogused bases and tops are "AGL" values and reconverted to MSL in this step.

Sorting the layers is a simple process and requires no further discussion. If more than four layers exist, then layers must be merged to form a maximum of four new layers. This process will be described later.

Finally, a new total cloud amount is calculated from the new and remaining original layers. This process will be discussed later.

7.3.2.1 Cloud Layer Merging

Since up to 10 cloud layers theoretically can exist from the bogus inputs, layers, on occasion, must be merged to reduce the number to no more than four. The merging of layers is based on fairly straightforward criteria. The layers must be of similar cloud types and must be close together (in the vertical). From these criteria, the following rules are established:

a. High cloud types can be merged only with other high cloud types. Likewise for middle and low clouds.

b. Cumulonimbus clouds will not be merged.

c. The layers' bases must be separated by no more than an amount based on the layer (potentially a different separation criterion for low, middle and high cloud layers). The method is:

(1) Start with the two highest-base layers and a set of separation criteria (e.g., 1000 meters for high clouds).

(2) If the layers are both high and the bases differ by no more than the high cloud separation criteria, merge the two high layers into a new high layer; likewise if the two layers were middle (or low) and if the middle (or low) separation criterion were met, merge the two to form a new (middle) or high layer.

(3) If all layers have been considered, but more than four layers still exist, increase the three separation criteria and repeat step 2. Keep increasing the acceptable separations until only four layers exist.

With this procedure, the number of layers will be reduced, but if any low (middle or high) layers existed, then at least one low (middle or high) layer will be retained.

When layers are merged, the newly-formed layers take on some of the qualities of the layers which were merged:

a. The new layer type is the type of the cloudier of the two merged layers; for equally cloudy layers, the type is that of the higher base layer.

b. The amount is the cloudier of the two merged layers; a "+2" offset will define the layer as a layer resulting from a merge (i.e., a 47 percent cloud cover layer in the database is actually a 45 percent cloud cover layer which resulted from a merger of two layers).

c. The new base is the lower of the bases of the two cloud layers.

d. The new top is the higher of the tops of the two cloud layers.

7.3.2.2 Total Cloud Calculation

After bogused layers have been inserted and merged as necessary, a new total cloud amount must be calculated to be consistent with the new layers. The new total cloud is determined by looping through each layer using:

$$\text{Total cloud} = \max(a,b) + (1-\max(a,b)) * \min(a,b) * N, \quad (6)$$

where a is the current layer, b is the total cloud and N is a vertical scaling factor. Total cloud initially is set to zero, but its updated value is retained through the layer looping.

7.3.3 Type/Amount Bogus

The third available option is to define the cloud type and amount only. This is the most frequently used option. In this case, the base and top are assigned by cloud type according to Table 7.3.

Table 7.3
DEFAULT CLOUD BASE AND CLOUD TOP HEIGHTS

Cloud Type (code)	Base (m)	Top (m)
Cumulonimbus (1)	915	9157
Stratus (2)	152	458
Stratocumulus (3)	762	1524
Cumulus (4)	915	2134
Altostratus (5)	2135	3353
Nimbostratus (6)	1829	3658
Altocumulus (7)	2439	4268
Cirrostratus (8)	5487	8231
Cirrocumulus (9)	6097	8536
Cirrus (10)	6097	8536

After the default bases and tops are incorporated with the types and amounts, the process is the same as in the type/amount/base/top option.

7.4 Limitations of the Bogus Process

Presently, AFGWC doesn't have the hardware to bogus every quarter orbit of data. Therefore, only about one out of every four quarter orbits may be bogused. However, when SDHS comes on line in 1988, AFGWC may be able to bogus at least three of every four quarter orbits.

SECTION 8. DATABASE CONTENTS

Aside from recognizing the specific parameters, a database user should recognize the deviation, meaning, and limitations of those specific parameters. This section will address those issues, but will not describe the specific database "word" structure. Any user of the RTNEPH database should obtain the specific database format from Air Force Global Weather Central or USAFETAC. The database contains four basic groups of data: the weather/visibility/total cloud group, layer source data, layer data, and diagnostic information. The data items and processor influences are described in each section as well.

8.1 Weather/Visibility/Total Cloud/Valid Time Information

This group essentially provides the most general information available at the grid point. The weather value is the WMO Code 4677 value (Table 4.2). The visibility is in WMO Code 4377 as shown in Table 7.2. Total cloud is in percent increments from 00 (clear) to 100 (overcast). Valid time is a coded deviation from the reference time as shown in Table 8.1. The parameter/processor relationships are shown in Table 8.2.

Table 8.1
TIME FLAG DEFINITIONS

Code	Meaning
0-229	The newest data at the gridpoint is this many hours older than the data reference time.
230	The newest data at the gridpoint is more than 229 hours older than the data reference time.
231-254	The number of hours never than data reference time - 230 (240 is 10 hours newer).
225	Data is more than 24 hours newer than the data reference time.

Table 8.2
PARAMETER/PROCESSOR RELATIONSHIPS

	Processor:	Conventional	Satellite	Merge	Bogus
	Weather	source		modify (1)	source
Paramter:	Visibility	source		modify (1)	source
	Total Cloud	source	source (4)	modify (2)	modify (2)
	Time	source	source	modify (3)	modify (3)

(1) The Merge Processor will delete weather/visibility information when data has failed a timeliness check or when satellite data overrides.

(2) The Merge Processor will recalculate total cloud from resultant combinations of satellite and conventional layers. The Bogus Processor will calculate new total cloud based on bogused layers.

(3) The Merge and Bogus Processors will modify the valid time based on time of newest data source used in cloud calculations.

(4) The Satellite Processor will provide both an infrared and visual total cloud, depending on the availability of these data.

As before, the layer parameters are also influenced by the individual processors as shown in Table 8.3.

Table 8.3
LAYER PARAMETER/PROCESSOR RELATIONSHIPS

	Processor:	Conventional	Satellite (2)	Merge	Bogus
	Amount	source	source	modify (1)	source
Parameter:	Type	source	source	modify (1)	source
	Base	source		modify (1)	source
	Top	source	source	modify (1)	source

(1) As always, the Merge can modify a layer in the merging process; modification could be deletion, change, or keep "as is".

(2) The Satellite Processor actually provides two sets of information, based on availability of visual and infrared data.

8.2 Cloud Layer Information

Cloud layer information is provided for up to four layers. Specifically each layer will be represented by amount, cloud type, base and top as shown in Table 8.4.

Table 8.4
CLOUD LAYER INFORMATION

Parameter	Range	Comments
Amount	0-100(%)	In 5% increments, except a +1 offset will indicate a thin layer (e.g., 51 = a thin layer with 50% coverage). A +2 offset will indicate a layer that was formed solely to meet the four layer constraint. A + 3 offset is possible if the layer is a thin, merged layer.
Type	0-25	See Table 4.5

Base	0-255	See Table 4.4
Top	0-255	Same as for base

8.3 Layer Source Information

Along with the parameters describing the meteorological properties, the RTNEPH provides data on the sources of the data. This information is especially useful in quality control of the model algorithms as well as for analysts using the RTNEPH database for studies. The source data are a set of yes/no indicators (or "flags") for whether the following were the data sources for the specific layers:

a. Low cloud persisted; indicates low clouds were retained when the Merge Processor stripped high and middle level clouds. See Section 6.4.3.1.

b. Estimated base; occurs when a layer top is known, but the base isn't. The base is then estimated by using the top and a default thickness.

c. Estimated top; occurs when a layer base is known, but the top isn't. The top is then estimated by using the base and a default thickness.

d. Best report from PIREP data; PIREP data was used to form the cloud layer.

e. Best report from RAOB data; RAOB data was used to form the cloud layer.

f. Best report from surface data; surface data was used to form the cloud layer.

g. Visual satellite data; visual satellite data was available for detection of the layer.

h. Infrared satellite data; infrared satellite data was available for detection of the layer.

For a particular layer, more than one source could be denoted. For example, a satellite-derived layer would have, at a minimum, a visual or infrared source indicated plus an estimated base indicated. An actual layer will have at least one source indicated.

The source flags are also a function of the processors, as shown in Table 8.5.

Table 8.5
SOURCE PARAMETER/PROCESSOR RELATIONSHIP

Processor	Conventional	Satellite	Merge (1)	Bogus
Source Parameter				
Low cloud persisted		source		
Estimated base	source	source	modify	source
Estimated top	source		modify	source
RAOB (best report)	source		modify	
PIREP (best report)	source		modify	
Surface obs (best rpt)	source		modify	
Visual satellite data		source	modify	
Infrared satellite data		source	modify	

(1) The Merge Processor modifies the source data in its selection or rejection of the data from a processor.

8.4 Diagnostic Information

To aid analysts maintaining the RTNEPH database, a significant amount of diagnostic information is provided in the database. Although this data is designed for quality control purposes, any user of the database might need to use this information, which mainly consists of flags like the layer source information. The diagnostic information is:

a. Bogus flag, which indicates whether the grid point has information derived from manually input data via the Bogus Processor; this flag is always cleared out in the archived databases.

b. Best Report flag, which indicates whether a best report from the Conventional Processor was included at this point.

c. Spread Data flag, which indicates whether conventional data from a best report was spread to this point from a nearby point with Best Report Data.

d. Visual Satellite flag, which indicates visual satellite data was available for consideration at the point.

e. Infrared Satellite flag, which indicates whether infrared satellite data was available for consideration at the point.

f. Low cloud persistence flag, which indicates whether low cloud was persisted from the previous analysis.

g. Visual satellite data only flag, which identifies that visual satellite data was the only data source available.

h. Second weather flag, which indicates that fog or haze was present in addition to the weather indicated in the primary weather information.

i. Time of oldest data at the grid point. This information coupled with the previously provided valid time of the data, provides a window indicating when all the data at the point was valid. This window is important for the definition of a valid time when the satellite and conventional data are, as in the usual case, of different, though close, valid times.

j. Best Report RAOB flag, which indicates that the grid point had a best report and that the best report had RAOB data.

k. Best Report PIREP flag, same as j, but for PIREP data.

l. Best Report surface observation flag, same as j, but for a surface observation.

m. Ice flag, which indicates the point was a water point with ice.

n. Snow flag, which indicates the ground was snow-covered at the point.

o. Tropics flag, which indicates that grid point is within the RTNEPH's tropical region.

p. Infrared daylight flag, which indicates the infrared data considered were daytime data.

q. Infrared sun-side flag, which indicates the infrared data at the point were on the sunward side of the quarter orbit of date.

r. Visual daylight flag, same as p, but for visual data.

s. Visual sun-side flag, same as q, but for visual data.

t. Sunglint flag, indicates the visual data fell in the sunglint cone.

u. Infrared satellite identifier, indicates which of the up to four meteorological satellites was the source of this point's infrared data. This is a coded value and, to be used, requires knowledge of RTNEPH chronology.

v. Visual satellite identifier, same as u, but for the source of visual satellite data.

Some of the above may seem redundant to earlier values, such as in the layer source information, but actually provide additional information. For example, the layer flag for visual data would indicate that a specific layer was actually based on visual data. The diagnostic entry for visual data, however, would indicate that visual data were considered in the analysis even though they were not an actual factor.

Just as with the earlier sets of information, one should consider the effects of the individual processors on the diagnostic entries. This is shown in Table 8.6.

Table 8.6
DIAGNOSTIC PARAMETER/PROCESSOR RELATIONSHIP

Parameter \ Processor	Conventional	Satellite	Merge	Bogus
Bogus flag			modify (1)	source
Best Report flag			source	
Spread flag			source	
Visual data flag		source	modify (1)	
IR data flag		source	modify (1)	
Low cloud persisted			source	
Visual data only flag		source		
Second Weather flag	source		modify (1)	
Oldest data (2)	source	source	modify	
Best Report - RAOB	source		modify (1)	
Best Report - PIREP	source		modify (1)	
Best Report - SURFACE	source		modify (1)	
Ice flag		source (3)		
Snow flag		source (3)		
Tropics flag		source		
IR daylight		source (3)		
IR sun-side		source (3)		
Visual daylight		source (3)		
Visual sun-side		source (3)		
Sunglint		source (3)		
IR satellite ID		source (3)		
Visual satellite ID		source (3)		

(1) The Merge Processor can modify a flag based on the Merge's decision to include or exclude the specific data.

(2) The Merge Processor calculates (modifies) the oldest data information based on inputs from the Conventional and Satellite processors (i.e., both can be sources for the input information).

(3) Actual sources are other databases. For example, the Satellite Processor gets the Ice flag from the terrain and geography database.

SECTION 9. QUALITY CONTROL

Quality control (QC) is difficult due to the large amount of data processed and the real time nature of the RTNEPH. Despite the difficulties, RTNEPH undergoes many different forms of QC to provide a comprehensive QC effort. These range from visual inspection of the analysis and noting deficiencies to changing the analysis via the Bogus Processor. We'll discuss each method in detail beginning with known RTNEPH problem areas.

9.1 Known RTNEPH Analysis Deficiencies

RTNEPH has several analysis deficiencies. These include:

a. Underinterpreting low clouds. This occurs when infrared satellite data is the only available source, the cloud temperatures are near the surface temperature and are therefore interpreted to be the surface. This problem can be "corrected" by tuning adjustments, but may lead to over interpretation in clear areas.

b. Coastline interpretation. Over or under interpretation may occur due to choosing a representative background field (brightness or temperature) to represent the gridpoint area. For instance, the sea-surface temperature is nearly always different from the land temperature. Therefore, when the Satellite Processor builds the histogram, it could be using a surface temperature more representative of the land and therefore may analyze clouds over water when there aren't any.

c. Snow and ice. RTNEPH is kept abreast of where snow and ice are located by the SNODEP model (Hall, 1986). If this information is incorrect, then the visual data may add a stratus cloud layer. Additionally, the snow temperature may be cooler than what the surface temperature model generates and therefore, over interpretation will result.

d. High plateaus. Areas such as the Tibetan plateau are routinely over interpreted due to the cold surface temperature.

e. Small-scale clouds. Small-scale clouds such as fair weather cumulus are difficult to detect due to their small footprint. They are routinely underinterpreted.

In addition to the analysis deficiencies mentioned above, cloud typing, thin cloud detection, and cloud thickness remains suspect. However, AFGWC presently doesn't have the means to QC these items.

9.2 Objective Analysis

The Satellite and Merge Processors do some error checks to prevent a poor analysis. In general, if a critical data file (RTNEPH analysis, geography, etc.) isn't available, then the program will abort. If the file isn't critical, then the processors will use default values.

9.2.1 Satellite Processor Quality Control

The Satellite Processor will verify if the correct data are processed by making sure the identifying information matches what is in the SGDB. Its other check is to verify the satellite data are within the look and zenith angle limit criteria for analysis.

9.2.2 Merge Processor Quality Control

The Merge Processor checks for cloud consistency for all analyses (conventional, satellite, and final) as outlined in section 6.3.1. If an error occurs, the Merge Processor "fixes" the inconsistency and prints diagnostic output.

9.3 Subjective Methods

Subjective methods provide the greatest amount of QC. These include bogus processor corrections, tuning, and written records of RTNEPH quality.

9.3.1 Bogus Processor Corrections

The Bogus Processor, described in Section 7, provides the most effective QC. Not only are problem areas identified, but they are fixed on the spot.

9.3.2 Tuning

The process of tuning the RTNEPH is to adjust parameter(s) in the tuning database to make a better analysis. The most common tune is to adjust the surface-minus-infrared skin temperature thresholds. Lowering these thresholds adds more clouds; raising the thresholds reduces clouds. This tune is normally done on a weekly basis. Other tunes such as adjusting the spreading radii criteria are done on an infrequent basis.

9.3.3 Quality Control Logs

RTNEPH QC at AFGWC is documented in two places. The first is the QC log for OL-A, USAFETAC. They use it to help their QC of the climatological RTNEPH database (Zamiska, 1986). AFGWC provides information for this QC log by overlaying the RTNEPH analysis against the SGDB. Satellite analysts annotate which RTNEPH boxes have problems. The second log is a subjective, random on-the-spot check done by the RTNEPH OIC. This log is attached to the cloud models section end-of-month QC reports.

SECTION 10. APPLICATIONS

10.1 Data Display Programs

The Display Processor for RTNEPH is NEFDIS. NEFDIS can display any of the RTNEPH data fields in any of four formats. The display formats are: A box-by-box display (one box per page) and polar stereographic hemispheric displays with scales of 1:7.5 million, 1:15 million, and 1:30 million. NEFDIS can display nearly all of the parameters from both the real-time and synoptic RTNEPH databases, as well as data from the satellite, best reports, geography, temperature, and background brightness support databases.

A second RTNEPH display program is CLDDIS. This program displays cloud fields for the AFGWC forecast floor (WFP). It displays tops, types, bases, and amounts for clouds at or above 10,000 feet with at least 4/8 coverage. It is useful for making horizontal weather depictions.

A third RTNEPH display program displays RTNEPH total cloud amounts in eighths in "DMSP" space. It is useful for determining bogus areas for the bogus processor. An example is shown in Figure 10.1. In Figure 10.1 notice the apparently incorrectly analyzed cloud amounts: areas of one-eighth coverage in north central Florida, in the Gulf of Mexico south of New Orleans, and south central Mississippi; and a few grid points analyzed as clear near Cuba that appear mostly cloudy or overcast and analyzed as clear; and an area of one and four-eighths northwest of Tampa Bay in the Gulf of Mexico. The analyst could bogus in his subjectively-determined cloud amounts in these areas.

10.2 Cloud Forecast Models

The RTNEPH database is primarily used to initialize the cloud forecast models 5LAYER, HRCP, and TRONEW.

10.2.1 5LAYER

The 5LAYER model (Crum, 1987), is the main cloud forecast model at AFGWC. 5LAYER produces cloud forecasts at the gradient, 850, 700, 500 and 300 mb levels. The forecasts are produced every three hours in the northern hemisphere and every six hours in the southern hemisphere. Forecasts are made for every three hour period out to 48 hours (northern) or 24 hours (southern). 5LAYER compresses the eighth-mesh RTNEPH data into a half-mesh, 100 nm resolution analysis. The analyses are made over a subset of each hemisphere known as the "octagon". 5LAYER's primary data sources are RTNEPH clouds and Global Spectral Model winds and temperatures. 5LAYER uses the analyses to forecast layered cloud amounts, total cloud, dew-point depressions, temperatures, present weather, and other fields.

10.2.2 HRCP

The High Resolution Cloud Prognosis model (HRCP) produces short range forecasts over selected areas of each hemisphere. HRCP uses 5LAYER and RTNEPH data to make 3, 6, and 9 hour forecasts of total cloud, layered cloud, total

Figure 10.1 RTNEPH total cloud analysis overlayed on DMSP satellite imagery in the Gulf of Mexico area. Numbers represent the eigths of cloud analyzed by the RTNEPH for that eighth-mesh grid point.

probability clear, and other parameters. The forecasts are eighth mesh, and are made using selected RTNEPH boxes (up to 13 boxes on any one run).

10.2.3 TRONEW

The TRONEW model produces half-mesh total cloud forecasts over the tropics (the areas not covered by 5LAYER). The forecasts are made for each three hour period out to 21 hours. The model uses diurnal persistence to make the forecast; the current analyzed cloud is the 24 hour forecast cloud. TRONEW takes RTNEPH total cloud data converted to total probability clear and compacts it to half mesh.

10.3 Other Models

AFGWC has models (AGROMET and PRANL) for precipitation estimation which use the RTNEPH data. The cloud types and amounts provide useful information for estimating precipitation in these models.

10.4 Archived Data

The RTNEPH synoptic database is saved on tape every three hours and sent to the USAF Environmental Technical Application Center, Operating Location A (OL-A, USAFETAC) at Asheville, NC. Potential users should contact OL-A, USAFETAC for information on obtaining the data.

SECTION 11. FUTURE PLANS

In response to an AFGWC computer upgrade, new data sources, and better algorithm techniques, the RTNEPH will undergo a technical enhancement. This enhancement will seek to reduce deficiencies in the RTNEPH described in section 9.1, producing a more accurate model.

11.1 Surface Temperature Model Rewrite

Perhaps the most significant enhancement to the RTNEPH will be the surface temperature model rewrite (see Appendices C and D of Fye, 1978). Recall that accurate surface temperatures are important to low cloud determination. Therefore, a more accurate surface analysis and forecast will help the RTNEPH. The tentative date for this rewrite completion is 1990.

11.2 Incorporation of SSMI/I Data

Special Sensor Microwave Imager (SSM/I), a passive microwave imager, will fly on new DMSP satellites. SSM/I information can be very helpful in determining whether clouds are present and the amount over snow and land areas, and provide inputs to surface temperature and snow/ice boundary models. Hughes Aircraft Corporation has been contracted to provide a multi-spectral module to process infrared and SSM/I data to be delivered in 1988.

11.3 1.5 nm SGDB (POSIDB)

The AFGWC SGDB will increase its horizontal resolution from 3 nm to 1.5 nm. This new database will be called Polar Orbiting Satellite Imagery Database (POSIDB). In addition to the increased horizontal resolution, POSIDB will increase both the infrared and visual grayshade resolution from 63 to 255 grayshades. Also, it will allow multiple channels to be stored vice only the present infrared and visual channels. These changes will help RTNEPH detect clouds with a smaller footprint than present and may also allow use of multi-spectral techniques.

11.4 Multi-Spectral Techniques

POSIDB may allow the addition of extra channels of data to be stored in the SGDB. Multi-spectral techniques using NOAA AVHRR data have been shown to be able to pick up low clouds and fog at night (Turner et. al., 1986). This is a present weakness of the RTNEPH due to its use of an IR thresholding technique. Other multi-spectral techniques may improve other RTNEPH analysis problems.

11.5 New Clustering Algorithm

AFGL is preparing their clustering algorithm (d'Entremont et. al., 1982) for use in the RTNEPH. Their algorithm appears to be more accurate in determining cloud layers and total cloud. It will be implemented after POSIDB is implemented because the algorithm requires a 16 X 16 array of grayshades. For an 1/8th mesh analysis, POSIDB will provide the correct resolution of grayshades.

11.6 1/16th Mesh RTNEPH

POSIDB, with its finer resolution, will allow RTNEPH to expand its horizontal resolution to 1/16th mesh (12.5 nm) in the mid 1990s. This will help RTNEPH to analyze smaller scale clouds better. It also may reduce the coastline interpretation problem.

11.7 Satellite Data Handling System Impacts

AFGWC's new Satellite Data Handling System (SDHS) will change how the Bogus Processor works. It will also open up application and QC options.

SDHS will allow the RTNEPH data to be overlayed on the displayed satellite imagery. After the cloud analyst encircles the bogused area, SDHS will fill in the bogused area. This will replace the fill-in part of the Bogus Processor. It won't however, replace the other parts of the Bogus Processor. SDHS will allow easier use of RTNEPH in horizontal weather depictions. Also, it will reduce the effort necessary for RTNEPH QC.

SECTION 12. CONCLUSION

We've discussed the AFGWC cloud analysis model, the RTNEPH. It continues to be a unique nephanalysis program providing timely, accurate cloud analysis at 25 nm horizontal resolution for the entire globe. RTNEPH will continue to change as new data techniques become available. Thus RTNEPH will continue to improve its analysis for users and applications programs.

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6WS, Hurlburt Field, FL 32544-5000.......................................1
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17WS/DON, Travis AFB, CA 94535-50000.....................................1
3350 TCHTG/TTGU-W, Stop 62, Chanute AFG, 61868-5000.......................3
Naval Research Laboratory, Code 4323, Washington, DC 20375...............1
NAVOCEANCOMFAC, NSTL, Bay St Louis, MS 39529-5002........................1
NOCD, Offutt AFB, NE, 68113-5000...1
COMNAVOCEAN, NSTL, MS 39529-5000...1
NEPRF, Monterey, CA 93943-5106...1
FNOC, Monterey, CA, 93943-51005..1
AFGL Library, Attn: SULLR, Stop 29, Hanscom AFB, MA 01731-5000...........3
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Atmospheric Sciences Laboratory, White Sands Missile Range, NM 88002-5501.....1
Technical Library, Dugway Proving Ground Dugway, UT 84033-5501................1
AWSTL, Scott AFB, IL 62225-5438...5
NOAA (W/FC), Federal Coordinators Office, Rockville, MD 20852.................1
National Meteorological Center, NOAA/W1NMC, Washington DC 20033...............1